U.S. Fish & Wildlife Service

Ouachita Rock Pocketbook
(Arkansia wheeleri)

Recovery Plan

March 2004

OUACHITA ROCK POCKETBOOK
(*Arkansia wheeleri* Ortmann and Walker, 1912)

RECOVERY PLAN

Prepared by

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for

Region 2
U.S. Fish and Wildlife Service
Albuquerque, New Mexico

Approved: H Dale Hall
Regional Director, U.S. Fish and Wildlife Service, Region 2

Date: 3/30/04

Concurrence: Robert L. Cook
Executive Director, Texas Parks and Wildlife Department

Date: March 3, 2004

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DEPARTMENT OF WILDLIFE CONSERVATION

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December 29, 2003

Dale Hall
Regional Director, USFWS Region 2
500 Gold Avenue S. W.
Albuquerque, NM 87102

Subject: Letter of Concurrence, Ouachita Rock Pocketbook Recovery Plan

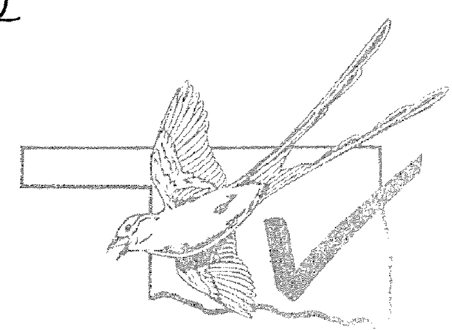
Dear Mr. Hall,

This letter responds to the final version of the Ouachita Rock Pocketbook Recovery Plan (Plan). The Department has reviewed the recovery plan and the recovery objectives. Based upon this review, we believe that the Plan contains a thorough assessment of the known historic and recent distributions of the Ouachita Rock Pocketbook and a complete summary of the data that have been collected with regard to this species' ecology and population biology. While data are limited for certain aspects of this species' biology, the recovery recommendations stated within the Plan appear to be biologically sound based upon our current knowledge and understanding of the Ouachita Rock Pocketbook. We trust that as new biological information is collected relative to this species, the Service will incorporate these data into future revisions of the Recovery Plan.

We concur with the U. S. Fish and Wildlife Service's findings and recommendations and will assist the Service in the implementation of the Ouachita Rock Pocketbook Recovery Plan within the constraints placed upon us by our funding and personnel limitations. If you have any questions regarding this letter, please direct them to Ron Suttles, Natural Resources Coordinator, at (405) 521-4616.

Sincerely,

Greg D. Duffy
Executive Director



DISCLAIMER

Recovery plans delineate reasonable actions that are believed to be required to recover and/or protect listed species. Plans are published by the U.S. Fish and Wildlife Service, sometimes prepared with the assistance of recovery teams, contractors, state agencies, and others. Objectives will be attained and any necessary funds made available, subject to budgetary and other constraints affecting the parties involved, as well as the need to address other priorities. Recovery plans do not necessarily represent the views nor the official positions or approvals of any individuals or agencies involved in the plan formulation, other than the U.S. Fish and Wildlife Service. They represent the official position of the U.S. Fish and Wildlife Service only after they have been signed by the Regional Director or Director as approved. Approved recovery plans are subject to modification as dictated by new findings, changes in species status, and the completion of recovery tasks.

ACKNOWLEDGMENTS

Dr. Caryn Vaughn, Oklahoma Biological Survey, is acknowledged for her extensive and important contributions to recent knowledge of the Ouachita rock pocketbook and the ecosystems it inhabits. Dr. Vaughn's research has produced much information vital to conservation of this species, providing the U.S. Fish and Wildlife Service a greatly improved basis from which to prepare this recovery plan. Many other researchers have contributed additional findings of value, and are acknowledged in the plan by citation of their works. The following U.S. Fish and Wildlife Service employees reviewed preliminary versions of this plan and provided valuable comments: Gloria Bell, Jerry B. Brabander, Steve Chambers, Kenneth D. Collins, George Divine, Daniel B. Fenner, David P. Flemming, Kenneth D. Frazier, Stephen L. Hensley, Susan O. Rogers, Tracy A. Scheffler, Charles M. Scott, and Noreen E. Walsh.

LITERATURE CITATION

Literature citations should read as follows:

> U.S. Fish and Wildlife Service. 2004. Ouachita Rock Pocketbook (*Arkansia wheeleri* Ortmann and Walker, 1912) Recovery Plan. Albuquerque, New Mexico. vi + 83p. + A-1-85p.

Copies of the Recovery Plan are available from:

U.S. Fish and Wildlife Service
Oklahoma Ecological Services Field Office
222 S. Houston, Suite A
Tulsa, OK 74127
Tele. 918/581-7458

or from the U.S. Fish and Wildlife Service Web Site at:

www.fws.gov

EXECUTIVE SUMMARY

RECOVERY PLAN FOR THE OUACHITA ROCK POCKETBOOK (*ARKANSIA WHEELERI*)

Current Status: This freshwater mussel is listed as endangered. It is known to exist in approximately 252 kilometers (km) or 157 miles (mi) of the Red River system and 179 km (111 mi) of the Ouachita River system. The only known substantial population (fewer than 1,800 individuals) inhabits a 141-km (88-mi) section of the Kiamichi River, Oklahoma. A smaller, attenuated population (less than 100 individuals) inhabits approximately 111 km (69 mi) of the Little River in Oklahoma and Arkansas, although quality habitat for the species prevails in only a limited portion (24 km/15 mi) of that section above the Mountain Fork River. Recent observations of the species in the Ouachita River, Arkansas, are rare and widely separated. The only other recent evidence of the species consists of single shells recovered from Pine and Sanders creeks, Texas, which enter the Red River near the Kiamichi River.

Habitat Requirements and Limiting Factors: The Ouachita rock pocketbook inhabits pools, backwaters, and side channels of rivers and large creeks in or near the southern slope of the Ouachita Uplift. This species occupies stable substrates containing gravel, sand, and other materials. The Ouachita rock pocketbook always occurs within large mussel beds containing a diversity of mussel species. Impoundments and water quality degradation continue to adversely impact this species' survival. These factors, proposals for further water resource development, potential land use changes, and other secondary developments constitute primary future threats. Additional known threats include direct disturbance of river channels, possible invasion of inhabited waters by the exotic zebra mussel, natural factors (the species' restricted distribution, sensitivity to environmental conditions, and low abundance), and a lack of knowledge regarding the species' reproduction.

Recovery Objective: Delisting.

Recovery Criteria: The Ouachita rock pocketbook may be reclassified as threatened by protecting the Kiamichi River population, and by reestablishing and protecting distinct viable populations in two streams outside the Kiamichi River system. Protection involves elimination of present and foreseeable threats (e.g., deauthorizing Tuskahoma Reservoir), determining biological requirements, maintenance of suitable habitats and specific fish host(s), and verification of conditions through monitoring. The interim criterion for delisting requires establishment and protection of distinct viable populations in four stream systems historically inhabited. The delisting criterion may be revised as additional information becomes available.

Actions Needed:
1. Preserve existing population and habitat in the Kiamichi River.
2. Determine if other viable populations exist, preserve any population(s) found; restore degraded habitats.
3. Determine reproduction, habitat, genetics, and captive propagation requirements.
4. Establish, if necessary, and protect two populations outside the Kiamichi River (for reclassification as threatened).
5. Develop an outreach program.
6. Develop an enhanced management program.
7. Establish, if necessary, and permanently protect viable populations in four stream systems historically inhabited by the species (for delisting).

Estimated Recovery Costs ($1,000's):

Year	Need 1	Need 2	Need 3	Need 4	Need 5	Need 6	Need 7	Total*
2003	149	226	245	40	25	218	0	903
2004	152	214	265	40	25	258	0	954
2005	142	190	190	40	2	235	0	799
2006	142	197	120	5	2	55	0	521
2007	127	182	110	15	2	115	0	551
2008	132	192	10	5	2	66	0	407
2009	147	207	0	0	2	66	40	462
2010	132	192	0	0	2	6	40	372
2011	132	192	0	0	2	6	40	372
2012	147	207	0	0	2	6	5	367
2013	107	142	0	0	2	6	15	272
2014	107	142	0	0	2	6	5	262
2015	122	157	0	0	2	6	0	287
2016	107	142	0	0	2	6	0	257
2017	107	142	0	0	2	6	0	257
2018	122	157	0	0	2	6	0	287
2019	107	142	0	0	2	6	0	257
2020	107	142	0	0	2	6	0	257
2021	122	157	0	0	2	6	0	287
2022	107	154	0	0	2	6	0	269
2023	107	142	0	0	2	6	0	257
Total*	2,624	3,618	940	145	88	1,097	145	8,657

Date of Reclassification: If criteria are met, the estimated date to reclassify to threatened is 2023.

Date of Delisting: A delisting date cannot be projected reasonably at this time.

* Total recovery costs, including habitat improvement costs needed for the species' recovery, will not be accurately known until the magnitude of specific threats is determined through research.

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PART I: INTRODUCTION

Description

The Ouachita rock pocketbook, *Arkansia wheeleri*, is a freshwater mussel, one of a group of mollusks in the class Bivalvia, family Unionidae (Turgeon *et al.* 1998). The species was first described by Arnold E. Ortmann and Bryant Walker in 1912. The genus, *Arkansia*, was named for the state in which the species was first found, and the species, *wheeleri*, for the person, Harry Edgar Wheeler, who discovered the species. The genus is monotypic, containing a single known species. Clarke (1981) proposed subsuming the genus *Arkansia* within the older genus *Arcidens*; however, subsequent authorities (e.g., Turgeon *et al.* 1988, 1998, Williams *et al.* 1993) did not maintain such practice and retained the genus name *Arkansia*. Turgeon *et al.* (1998) comprise a committee set up to standardize common and scientific names of mollusks, and their findings are endorsed by the American Fisheries Society, the former Council of Systematic Malacologists, and the American Malacological Society. Nevertheless, some references use *Arcidens wheeleri* as the scientific name. The standardized common name for *A. wheeleri* is the Ouachita rock pocketbook. Other reported common names include Wheeler's pearly mussel, Wheeler's rock-pocketbook, the Arkansas rock-pocketbook, and a hyphenated form of the current standard name (Greenwalt 1974, Howells *et al.* 1996). The U.S. Fish and Wildlife Service (FWS) listed the Ouachita rock pocketbook as endangered in 1991 (Federal Register 56:54950-54957), without critical habitat.

Readily available references depict the shell of the Ouachita rock pocketbook in color photographs (Harris and Gordon 1990, Williams *et al.* 1993, Howells *et al.* 1996, Beacham *et al.* 2001), black-and-white photographs (Ortmann and Walker 1912, Webb 1942, Johnson 1980, Branson 1983, Howells *et al.* 1996), and drawings (Clench 1959, Burch 1975, Clarke 1981, Pennak 1989). This plan includes an image of the species (Figure 1), which also can be found within the FWS's endangered species website (http://endangered.fws.gov). The Ouachita rock pocketbook does not have a sexually dimorphic shell, both sexes appearing the same. The shell is subcircular to subovate to subquadrate in profile, truncated posteriorly, moderately inflated, up to 112 millimeters (mm) (4.4 inches) long, 87 mm (3.4 inches) high, and 60 mm (2.4 inches) wide, moderately heavy, somewhat thickened anteriorly, up to 6 mm (0.24 inches) thick, and half as thick posteriorly. The periostracum (outer shell layer) is chestnut-brown to black with a silky luster, and appears slightly iridescent when wet. The umbos are prominent, and project over a well-defined lunule depression. The posterior half of the shell is sculptured by irregular, oblique ridges that are sometimes crossed by smaller ridges or sometimes indistinct. Beak sculpturing, rarely intact, is very restricted and consists of weak double loops. The nacre (inner shell lining) is usually salmon-colored above the pallial line, white to light blue below, with a dark prismatic border. The shell has the so-called "complete" dentition for unionid bivalves, with all hinge teeth usually well-developed. The anterior left pseudocardinal and right pseudocardinal are both curved and parallel to the lunule; the posterior left pseudocardinal joins a conspicuous, flange-like, interdental projection that runs to the lower lateral. The lateral teeth are moderately short; the upper left lateral is sometimes reduced (Ortmann and Walker 1912, Johnson 1980, Clarke 1981, C.M. Mather, University of Science and Arts of Oklahoma, *in litt.* 2001).

Ortmann and Walker (1912) and Clarke (1981) described the soft anatomy of the Ouachita rock pocketbook, and Clarke (1981) included illustrations of a whole specimen and details of its gills. The soft parts agree in structure with anatomy characterized generally for the subfamily Anodontinae. Ortmann and

Figure 1. Ouachita rock pocketbook, *Arkansia wheeleri*. Photograph by Patricia Mehlhop.

Walker (1912) noted special agreement in the mantle edge and outer marsupial gill. In life, the incurrent opening is separated from the excurrent opening by appression of opposing mantle edges. The excurrent opening is separated from a supra-anal opening by a mantle connection. The incurrent opening is lined with three rows of small, flattened papillae; the excurrent opening is lined with one row of tiny, flattened papillae. The external membrane of the outer demibranch (gill) joins the mantle posteriorly to form a complete gill-diaphragm. The anterior end of the inner gills usually reaches between the posterior base of the labial palps and the anterior end of the outer gills. The inner lamina of the inner gills is free from the abdominal sac, except for a short distance at the anterior end. The labial palps are of medium size and subfalcate, with their posterior margins connected for about one-third of their length. The external membrane of the outer demibranch is openly porous, like a woven net. The gills have well-developed septa and water tubes. The septa are rather distant in the male and in the inner gill of the female. The outer gill alone is marsupial in the female, with very close septa. The edge of the marsupium is slightly thickened (Ortmann and Walker 1912, Clarke 1981).

Mussel identification is complex and relies on characters that may appear subtle to persons without specialized training. As a result, laypersons may confuse the Ouachita rock pocketbook with other freshwater mussels and may even question its validity as a separate species. However, *A. wheeleri* exhibits a number of characteristics that clearly distinguish it from other species. Furthermore, it shows no intergradation with other described mussel species and has been recognized by biologists as a distinct species from the time of its discovery. It is most likely to be mistaken for certain forms of two more widespread and common species, which it can resemble superficially: (1) the pimpleback, *Quadrula pustulosa* (I. Lea, 1831), and (2) the threeridge, *Amblema plicata* (Say, 1817). The Ouachita rock pocketbook can be differentiated from both species externally by its slightly iridescent periostracum and internally by its high interdental flange. In the pimpleback, the periostracum often remains a lighter shade of brown in adults and often includes greenish rays marking the umbos. The threeridge also exhibits oblique ridges but these tend to be more pronounced than those exhibited by the Ouachita rock pocketbook. The closest living relative to *A. wheeleri* is the rock pocketbook, *Arcidens confragosus* (Say, 1829). *A. wheeleri* can be distinguished from *A. confragosus* by the former species' heavier and more inflated shell; by its fuller, more anterior beaks; by its possession of a lunule; by its restriction of heavy sculpturing to the posterior half of the shell; by its much reduced beak sculpturing; and by its more greatly developed lateral teeth. Other subtle characteristics further differentiate the Ouachita rock pocketbook from other mussel species.

Ortmann and Walker (1912) designated the type locality for *A. wheeleri* as "Old River, Arkadelphia, Arkansas." Wheeler (1918) described the type locality as a series of oxbows connected to the Ouachita River, north of Arkadelphia, Clark County, Arkansas. The holotype of *A. wheeleri* was reported by Ortmann and Walker (1912) to be in the Walker collection. Paratypes were reported to have been placed in collections of the Carnegie Museum, the Philadelphia Academy of Science, the U.S. National Museum, and Reverend H.E. Wheeler. Johnson (1980) reported the holotype to be catalogued at the Museum of Zoology, University of Michigan (which acquired the Walker collection), and the Wheeler collection deposited at the Alabama Museum of Natural History (ALMNH), University of Alabama. Subsequently, however, much of the ALMNH mollusk collection, including the former Wheeler collection, was transferred to the Florida Museum of Natural History (FLMNH), University of Florida (Fred G. Thompson, FLMNH, pers. comm. 1999).

In accordance with the FWS's Species Recovery Priority System (Federal Register 48:43098-43105, 51985), the Ouachita rock pocketbook has been assigned a recovery priority of 4C.

Distribution and Abundance

To facilitate discussion of the Ouachita rock pocketbook's distribution, this plan reviews historical records separately from recent records. Historical records consist of those obtained prior to 1975, or that appear to represent occurrences of the species prior to 1975 (e.g., later discovery of pre-1975 shells). Recent records represent occurrences in 1975 or later. The term "natural range" denotes the total known range of the species, based on both historical and recent records (Figure 2).

Historical (prior to 1975)

Early records of *A. wheeleri* were published by Ortmann and Walker (1912), Wheeler (1918), Ortmann (1921), and Isely (1925). No additional discoveries of the species were reported until Stansbery (1970) and Valentine and Stansbery (1971), although some preceding reports (e.g., Brooks and Brooks 1931, Johnson 1956, and Parodiz 1967) accounted for specimens from early collections. Frierson (1927) erroneously reported *A. wheeleri* from the Arkansas River in Oklahoma. Records reported by Johnson (1977, 1979, 1980), Clarke (1981), and Bogan and Bogan (1983), while made after 1975, included specimens that represented historical populations. Published records reveal historical populations of the Ouachita rock pocketbook in three areas: the Ouachita River, southcentral Arkansas; the Kiamichi River, southeastern Oklahoma; and the Little River, southwestern Arkansas. Pre-1975 museum specimens of *A. wheeleri* for which data are available correspond fairly closely with the published records discussed (Table 1). Collection records indicate historical populations of the Ouachita rock pocketbook in the same general areas indicated by literature records (http://www.flmnh.ufl.edu; R. Hershler, National Museum of Natural History, *in litt.* 1993; R.I. Johnson, Museum of Comparative Zoology, *in litt.* 2001; M. Kitson, Academy of Natural Sciences of Philadelphia, *in litt.* 2001; C.A. Mayer and K.S. Cummings, Illinois Natural History Survey, *in litt.* 2001, N. McCartney, University of Arkansas, *in litt.* 2001, T.A. Pearce, Carnegie Museum of Natural History, *in litt.* 2002, and G.T. Watters, Ohio State University, *in litt.* 2001).

As stated above, the type locality for the Ouachita rock pocketbook was explained by Wheeler (1918) to be a set of oxbows of the Ouachita River north of Arkadelphia. Additional locality details were quoted from the holotype label by Clarke (1981). Wheeler gave the Ouachita River proper below Arkadelphia as another locality inhabited by *A. wheeleri* but stated that it rarely occurred there. Museum records show several lots of the species, some containing multiple specimens, collected from the Old River locality within a short span of years (even without counting cases where the collection date is unknown). A small number of lots seem to have originated from the Ouachita River (proper) locality, near or below Arkadelphia, during the same general time frame. Most of the early specimens from the Ouachita River system were likely collected by Wheeler.

Ortmann (1921) reported a single *A. wheeleri* shell collected in 1919 from the Kiamichi River at Antlers, Pushmataha County, Oklahoma. Isely (1925) reported a specimen collected in 1912 from the Kiamichi River at Tuskahoma, also in Pushmataha County. In 1968, Valentine and Stansbery (1971) found *A. wheeleri* in the Kiamichi River at Spencerville Crossing, Choctaw County, a site since flooded by Hugo Reservoir. Clarke (1981) reported data on three female specimens collected in 1971 by D.H. Stansbery, from the Kiamichi River southeast of Clayton, Pushmataha County. Bogan and Bogan (1983) reported a shell from an archaeological site on Jackfork Creek (a tributary of the Kiamichi River) in Pushmataha County,

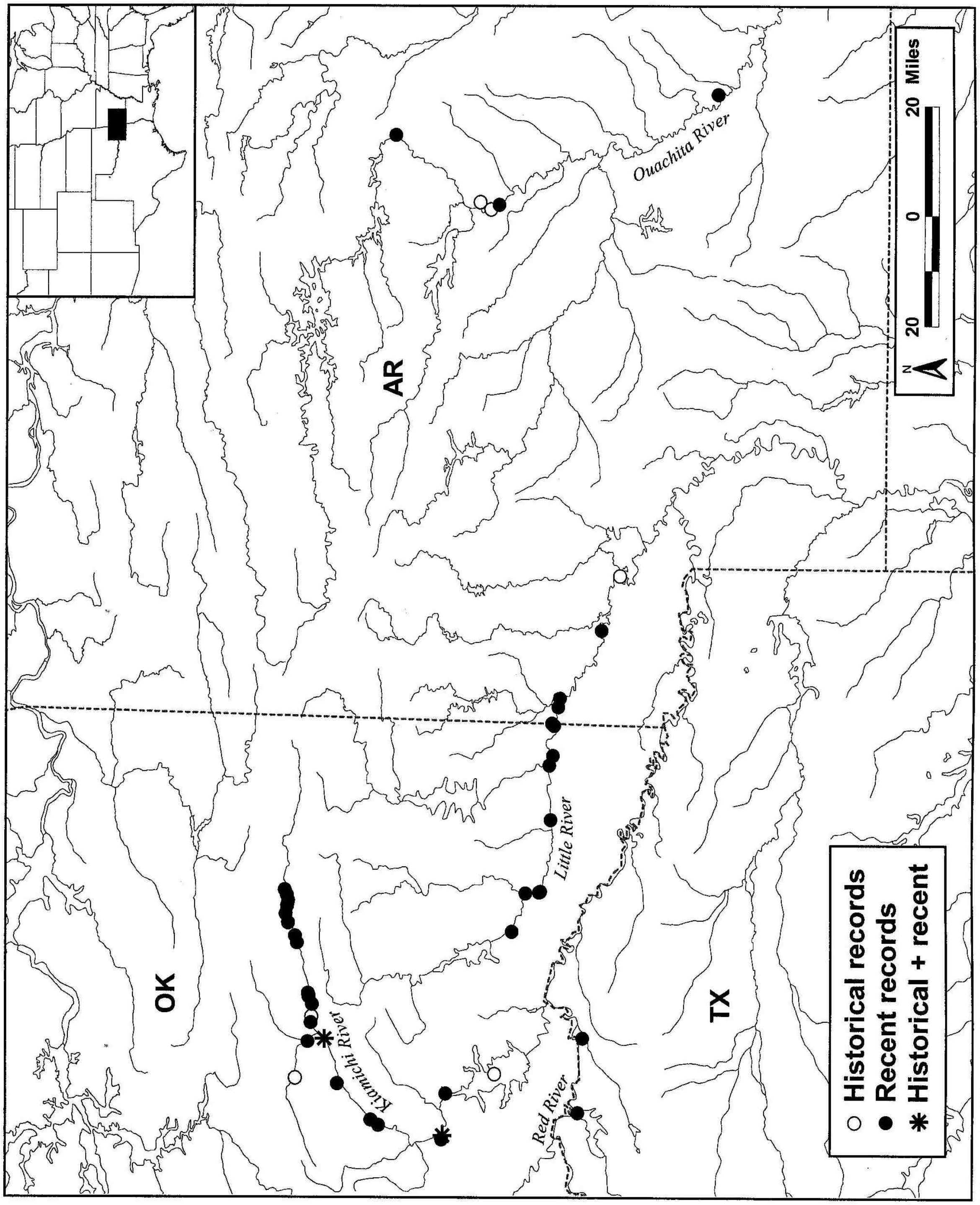

Figure 2. Distribution of Ouachita rock pocketbook, *Arkansia wheeleri*.

TABLE 1. SUMMARY OF AVAILABLE HISTORICAL RECORDS (PRE-1975) OF *ARKANSIA WHEELERI*.[1]
Entries are arranged chronologically by distinct localities. Bold type indicates the first record for the locality, normal type indicates subsequent records.

Stream	State	Locality Description / Collector(s)	Year	Reference
Ouachita River	AR	**Old River**, Arkadelphia / H.E. Wheeler	≤1911	ANSP 105546, CM 61.5357, CM 61.5358 (Brooks and Brooks 1931, Parodiz 1967, Johnson and Baker 1973, Kitson *in litt.* 2001, Pearce *in litt.* 2002)
Ouachita River	AR	Old River, Arkadelphia	≤1912	Ortmann and Walker (1912)
Ouachita River	AR	Old River, Arkadelphia; Ouachita Road, 3 mi. [4.8 km] above Arkadelphia	≤1912	UMMZ 105514 (Johnson and Baker1973, Johnson 1977, 1979, 1980, Clarke 1981)
Ouachita River	AR	Old River, Arkadelphia	1912	FLMNH 180629 (http://www.flmnh.ufl.edu)
Ouachita River	AR	Old River, Arkadelphia / H.E. Wheeler (CM 61.6162, FLMNH 64100)	1913	CM 61.6162, FLMNH 64100, FLMNH 180627, FLMNH 180628, INHS 20115 (http://www.flmnh.ufl.edu, Parodiz 1967, Mayer and Cummings *in litt.* 2001, Pearce *in litt.* 2002)
Ouachita River	AR	Old River, north of Arkadelphia	≤1918	Wheeler (1918)
Ouachita River	AR	Old River, Arkadelphia	1919[2]	ANSP 48318 (Kitson *in litt.* 2001)
Ouachita River	AR	Old River, Arkadelphia	≤1938	ARK 38-7-223 ex A.J. Brown (McCartney *in litt.*2001)
Ouachita River	AR	Old River, Arkadelphia / H.E. Wheeler (FLMNH 268996, all MCZ lots, USNM 218946)	[3]	FLMNH 180626, FLMNH 268996, MCZ 23319, MCZ 46759, MCZ 135712, USNM 218946, USNM 228905 (http://www.flmnh.ufl.edu, Clarke 1981, Hershler *in litt.* 1993, Johnson 1956, 1977, *in litt.* 2001)
Ouachita River	AR	**Arkadelphia**	1913	FLMNH 65593 (http://www.flmnh.ufl.edu)
Ouachita River	AR	Arkadelphia	1914	INHS 20113 (Mayer and Cummings *in litt.* 2001)
Ouachita River	AR	Below Arkadelphia	≤1918	Wheeler (1918)
Ouachita River	AR	Arkadelphia	1936	OSUM 43375, ex W.F. Webb (Watters *in litt.* 2001)
Ouachita River	AR	Arkadelphia		FLMNH 175092, FLMNH 225931, UMMZ (http://www.flmnh.ufl.edu, Johnson 1980)

TABLE 1. (Continued)

Stream	State	Locality Description / Collector(s)	Year	Reference
Ouachita River	AR	**Not specified**	≤1920	INHS 20114 (Mayer and Cummings *in litt.* 2001)
Kiamichi River	OK	**Tuskahoma**	1912	Isely (1925)
Kiamichi River	OK	**1.2 mi. SE of Clayton at U.S. Rt. 271** / D.H. Stansbery	1971	OSUM 32816 (Clarke 1981, Branson 1983, Watters *in litt.* (2001)
Kiamichi River	OK	**Antlers** / D.K. Gregor	1919	Ortmann (1921)
Kiamichi River	OK	Antlers / D.K. Greger	1919	CM 61.9830 (Johnson 1980, Pearce *in litt.* 2002)
Kiamichi River	OK	**Spencerville Crossing**, 1 mi. S of OK Rt. 93, 9 mi. NE of U.S. Rt. 70 / B. Valentine	1968	Valentine and Stansbery (1971), Clarke (1981)
Kiamichi River	OK	Spencerville Crossing, 8.5 mi. NE of Hugo / B. D. Valentine and class	1968	OSUM 20246, USNM uncat., ex OSUM (Hershler *in litt.* 1993, Watters *in litt.* 2001)
Jackfork Creek	OK	**Bug Hill**, 0.25 mi. NE of confluence of Jackfork and North Jackfork creeks	1981-1982	Bogan and Bogan (1983)
Little River	AR	**White Cliffs** / W.F. Webb	1933	ANSP 160466 (Clarke 1981, Kitson *in litt.* 2001)
Little River	AR	White Cliffs		UMMZ (Johnson 1980)

Notes

1. Includes duplicative records where an incomplete accounting exists between literature and museum records.
2. "Cotype" designation, label similarities, and original lot number (1897) shared with ANSP 105546 indicate that recorded date may be in error.
3. "Cotype"/paratype designation indicates at least some specimens likely collected ≤1912.

Key to acronyms used in Table 1

ANSP - Academy of Natural Sciences of Philadelphia
ARK - University of Arkansas, Fayetteville
CM - Carnegie Museum of Natural History
FLMNH - Florida Museum of Natural History
INHS - Illinois Natural History Survey
MCZ - Museum of Comparative Zoology
OSUM - Ohio State University, Museum of Biological Diversity
UMMZ -University of Michigan, Museum of Zoology
USNM - National Museum of Natural History
≤ - From specified year or earlier

indicating that the species might have inhabited the creek previously. The archaeological site and adjoining creek have since been flooded by Sardis Reservoir. Most historical reports of the Ouachita rock pocketbook from the Kiamichi River drainage match known museum specimens, and none of the latter indicate additional (unpublished) historical occurrences.

Johnson (1980) and Clarke (1981) reported *A. wheeleri* specimens collected from the Little River at White Cliffs, Little River County-Sevier County boundary, Arkansas. One of the museum specimens on which those reports were based is recorded as collected in 1933, and all those from White Cliffs appear to represent occurrences prior to 1975.

<u>Recent</u> (1975 to present)

Efforts to locate the Ouachita rock pocketbook increased during the 1980's and 1990's. Knowledge of the species' recent distribution (Table 2) derives largely from published records, and many specimens collected in recent years have yet to be deposited in museum collections or are among material waiting to be catalogued. Also, recent surveyors have more commonly returned live individuals of *A. wheeleri* to their habitats, after documenting occurrences with photography and other methods. Localities of recent occurrence are described here with only moderate precision, which is sufficient for most planning purposes without creating a significant risk of harm to individuals and habitats that might still exist at those localities. The following sources, unless noted otherwise, report observations during the year published.

Recent surveys indicate that the Ouachita rock pocketbook still occurs in the Ouachita River in Arkansas, but in very low abundance. Gordon and Harris (1983) and Harris and Gordon (1987) found relict shells in the Ouachita River at the mouth of Saline Bayou, Clark County, and at Malvern, Hot Spring County. Those authors did not attempt to date shells collected. Clarke (1987) found no evidence of the species in the Ouachita River. Posey *et al.* (1996) found, documented, and replaced a single live specimen of *A. wheeleri* in the Ouachita River southeast of Camden, Ouachita County-Calhoun County boundary, in 1995. That record extended the species' known range in the Ouachita River to a total of approximately 179 river kilometers (km) or 111 river miles (mi), although recent occurrences within that range are rare and widely separated. Among recent surveys of the Ouachita River, Gordon and Harris (1983) and Clarke (1987) reported extensive and considerable degradation of the localities historically inhabited by the Ouachita rock pocketbook.

The species continues to occur in the Kiamichi River. Mather (*in litt.* 2001) and Magrath found live individuals and shells between Clayton and Eubanks, Pushmataha County, during 1982-1986, and again during 1991-1995. Clarke (1987) reported a healthy but diffuse population within what he described as an 80-km (50-mi) reach of the Kiamichi River, from near Albion to near Antlers, all within Pushmataha County. The FWS believes 103 km (64 mi) is a more accurate estimate of that reach. Mehlhop and Miller (1989) subsequently documented that population to occupy an additional 22 km (13.6 mi) of the Kiamichi River, for an overall distribution in the river from near Whitesboro, LeFlore County, to near Antlers.

In a three-year (1990-1992) study of the Kiamichi River mainstem, Vaughn *et al.* (1993) found living Ouachita rock pocketbooks at six sites in the river, all within the range documented by Clarke (1987) and Mehlhop and Miller (1989). In 1993, Vaughn found *A. wheeleri* alive at an additional locality immediately upstream from Hugo Reservoir (C.C. Vaughn, Oklahoma Natural Heritage Inventory, *in litt.* 1994), extending

TABLE 2. SUMMARY OF AVAILABLE RECENT RECORDS (1975 AND LATER) OF *ARKANSIA WHEELERI*.[1] *Entries are arranged chronologically by distinct localities. Bold type indicates the first record for the locality, normal type indicates subsequent records.*

Stream	State	Locality Description / Collector(s)	Year	Reference
Ouachita River	AR	**Near Malvern** / J.L. Harris		Harris and Gordon (1987)
Ouachita River	AR	**Near mouth of Saline Bayou** / M.E. Gordon, W.K. Welch and J.L. Harris	1983	Gordon and Harris (1983)
Ouachita River	AR	Below **[9 mi. SE of] Camden, river mile 334** / W.R. Posey, C. Davidson and V. Posey	1995	P. Hartfield, FWS *in litt.* (1995), Posey *et al.* (1996), Harris *et al.* (1997)
Kiamichi River	OK	**2+ mi. WSW of Whitesboro** / P. Mehlhop and E. Miller	1989	Mehlhop and Miller (1989)
Kiamichi River	OK	**3+ mi. WSW of Whitesboro** / P. Mehlhop and E. Miller	1989	Mehlhop and Miller (1989)
Kiamichi River	OK	**4+ mi. WSW of Whitesboro** / P. Mehlhop and E. Miller	1989	Mehlhop and Miller (1989)
Kiamichi River	OK	[**5+ mi. WSW of Whitesboro**] Study site 1	1992	Vaughn *et al.* (1993)
Kiamichi River	OK	**6+ mi. WSW of Whitesboro** / P. Mehlhop and E. Miller	1989	Mehlhop and Miller (1989)
Kiamichi River	OK	**5+ mi. ENE of Albion** / P. Mehlhop and E. Miller	1989	Mehlhop and Miller (1989)
Kiamichi River	OK	**2+ mi. E of Albion**, below bridge / A.H. Clarke	1987	Clarke (1987)
Kiamichi River	OK	2+ mi. ESE of Albion, below bridge / P. Mehlhop and E. Miller, ± C.M. Mather	1989	Mehlhop and Miller (1989)
Kiamichi River	OK	[2+ mi. ESE of Albion] Study site 2	1990, 91, 92	Vaughn *et al.* (1993)
Kiamichi River	OK	**1+ mi. SE of Albion** / P. Mehlhop, C.M. Mather and E. Miller	1989	Mehlhop and Miller (1989)
Kiamichi River	OK	**1+ mi. above Dry Creek** / P. Mehlhop and E. Miller, ± C.M. Mather	1989	Mehlhop and Miller (1989)
Kiamichi River	OK	**4+ mi. E of Tuskahoma** / P. Mehlhop, C.M. Mather and E. Miller	1989	Mehlhop and Miller (1989)
Kiamichi River	OK	**3+ mi. E of Tuskahoma** / A.H. Clarke and C.M. Mather	1987	Clarke (1987)

TABLE 2. (Continued)

Stream	State	Locality Description / Collector(s)	Year	Reference
Kiamichi River	OK	3+ mi. E of Tuskahoma / A.H. Clarke and C.M. Mather	1987	ANSP 369314 (Kitson *in litt.* 2001)
Kiamichi River	OK	**1+ mi. E of Tuskahoma** / A.H. Clarke, J.J. Clarke and C.M. Mather	1987	Clarke (1987)
Kiamichi River	OK	1+ mi. E of Tuskahoma / A.H. Clarke and C.M. Mather	1987	ANSP 369315 (Kitson *in litt.* 2001)
Kiamichi River	OK	[**1+ mi. W of Tuskahoma**] Study site 3	1990, 91, 92	Vaughn *et al.* (1993)
Kiamichi River	OK	<1 mi. S **[1+ mi. SE] of Clayton** / C.M. Mather	1982	USAO 1786 (Mehlhop and Miller 1989, Mather *in litt.* 2001)
Kiamichi River	OK	1+ mi. SSE of Clayton / C.M. Mather	1986	USAO 3749 (Mehlhop and Miller 1989, Mather *in litt.* 2001)
Kiamichi River	OK	1+ mi. SSE of Clayton, below U.S. Rt. 271 bridge / A.H. Clarke and C.M. Mather	1987	Clarke (1987)
Kiamichi River	OK	<1 mi. S [1+ mi. SSE] of Clayton near U.S. Hwy 271 / C.M. Mather	1995	USAO 7821 (Mather *in litt.* 2001)
Kiamichi River	OK	**Near Stanley**, <1 mi. below ford / A.H. Clarke and C.M. Mather	1987	Clarke (1987)
Kiamichi River	OK	<1 mi. E of Stanley, <1 mi. below ford / P. Mehlhop	1988	Mehlhop and Miller (1989)
Kiamichi River	OK	<1 mi. E of Stanley, near and below ford / P. Mehlhop and E. Miller	1989	Mehlhop and Miller (1989)
Kiamichi River	OK	[Near Stanley] Study site 5	1990, 1992	Vaughn *et al.* (1993)
Kiamichi River	OK	Near Stanley / C.M. Mather	1991	USAO 8108 (Mather *in litt.* 2001)
Kiamichi River	OK	Near Stanley / C.M. Mather	1992	USAO 6574 (Mather *in litt.*1992, 2001)
Kiamichi River	OK	**[S of Dunbar]** 16+ mi. SW of Clayton near State Hwy 2 / L.K. Magrath	1983	USAO 2415 (Mehlhop and Miller 1989, Mather *in litt.* 2001)
Kiamichi River	OK	Near State Hwy 2 N of Antlers, N crossing / C.M. Mather	1984	USAO 2837 (Mehlhop and Miller 1989, Mather *in litt.* 2001)
Kiamichi River	OK	2+ mi. NNE of Eubanks / A.H. Clarke and C.M. Mather	1987	Clarke (1987)

TABLE 2. (Continued)

Stream	State	Locality Description / Collector(s)	Year	Reference
Kiamichi River	OK	[S of Dunbar] Study site 6	1990, 91, 92	Vaughn *et al.* (1993)
Kiamichi River	OK	[**N of Eubanks**] 14+ mi. NNE of Antlers near State Hwy 2 / C.M. Mather	1982	USAO 1771 (Mehlhop and Miller 1989, Mather *in litt.* 2001)
Kiamichi River	OK	Near State Hwy 2 N of Antlers, S crossing / C.M. Mather	1984	USAO 2831 (Mehlhop and Miller 1989, Mather *in litt.* 2001)
Kiamichi River	OK	Between Clayton and Antlers near State Hwy 2 (S crossing) / C.M. Mather	1986	USAO 4214 (Mehlhop and Miller 1989, Mather *in litt.* 2001)
Kiamichi River	OK	[N of Eubanks] Study site 7	1990, 1991	Vaughn *et al.* (1993)
Kiamichi River	OK	Near Eubanks crossing on State Hwy 2 / C.M. Mather	1995	USAO 7817 (Mather *in litt.* 2001)
Kiamichi River	OK	**1+ mi. N of Antlers**, <1 mi. above U.S. Rt. 271 / A.H. Clarke and C.M. Mather	1987	Clarke (1987)
Kiamichi River	OK	**1+ mi. NNE of Antlers**, above U.S. Rt. 271 / A.H. Clarke and C.M. Mather	1987	Clarke (1987)
Kiamichi River	OK	1 mi. N of Antlers / A.H. Clarke and C.M. Mather	1987	ANSP 369313 (Kitson *in litt.* 2001)
Kiamichi River	OK	**[Near mouth of Big Waterhole Creek,]** immediately above Lake Hugo / C.C. Vaughn	1993	Vaughn *in litt.* (1994)
Jackfork Creek	OK	**<1 mi. downstream from Sardis Dam** / A.D. Martinez	1997	A.D.M., unpublished data, Meier and Vaughn (1998)
Little River	OK	1+ **[2+] mi. SW of Wright City**, near railroad crossing / J.A.M. Bergmann and C.M. Mather	1991	Bergmann coll. (Mather pers. comm. 1993, *in litt.* 2001)
Little River	OK	2+ mi. W of Wright City, near railroad crossing / C.M. Mather and J.A.M. Bergmann	1993	USAO 7049 (Mather *in litt.* 2001)
Little River	OK	**Near Thompson Bend, below mouth of Glover River** / C.C. Vaughn, M. Pyron and M. Craig	1993	Vaughn (1994)
Little River	OK	**2+ mi. N of Garvin,** above Possum Ford Bend / C.C. Vaughn, M. Winston, E.K. Miller and C.M. Mather	1992	Mather *in litt.* (1992), Vaughn (1994)

TABLE 2. (Continued)

Stream	State	Locality Description / Collector(s)	Year	Reference
Little River	OK	**1+ mi. N of Garvin** / C.M. Mather and J.A.M. Bergmann	1991	USAO 6293 (Mather pers. comm. 1993, *in litt.* 2001)
Little River	OK	**Near mouth of Yashoo Creek** / C.C. Vaughn, K.J. Eberhard, M. Craig and C.M. Taylor	1994	Vaughn *et al.* (1995)
Little River	OK	[Near mouth of Yashoo Creek] Sampling site 23		Vaughn and Taylor (1999)
Little River	OK	**<1 mi. above confluence with Mountain Fork River** / C.C. Vaughn, K.J. Eberhard, M. Craig and C.M. Taylor	1994	Vaughn *et al.* (1995)
Little River	OK	**Near mouth of Black Creek** / C.C. Vaughn, K.J. Eberhard, M.Craig and C.M. Taylor	1994	Vaughn *et al.* (1995)
Little River	AR	**<1 mi. E of OK/AR boundary** / A.H. Clarke and J.J. Clarke	1987	Clarke (1987)
Little River	AR	**<1 mi. NE of OK/AR boundary**, near mouth of Buck Creek / A.H. Clarke	1987	Clarke (1987)
Little River	AR	**<1 mi. upstream from LRCC boat ramp** / C.C. Vaughn, K.J. Eberhard, M. Craig and C.M. Taylor	1994	Vaughn *et al.* (1995)
Little River	AR	1+ [<1?] mi. **W of AR Hwy 41**[2] / M.E. Gordon and J.L. Harris	1983	Gordon and Harris (1983)
Little River	AR	<1 mi. W of AR Hwy 41, SW of Horatio / J. Harris and M. Gordon	1983	ANSP 358806 (Kitson *in litt.* 2001)
Little River	AR	**4+ mi. NW of U.S. Hwy 59/71 crossing** / M.E. Gordon and J.L. Harris	1983	Gordon and Harris (1983)
Sanders Creek	TX	**Below Pat Mayse Lake near TX Hwy 197 crossing** / C.M. Mather and J.A.M. Bergmann	1993	Howells *et al.* (1996, 1997) USAO 7052 (Mather *in litt.* 2001)
Pine Creek	TX	**TX Hwy 906 bridge near Faulkner** / J.A.M. Bergmann	1992	Mather pers. comm. (1993), Howells *et al.* (1996, 1997)

Notes

1. Includes duplicative records where an incomplete accounting exists between literature and museum records.
2. Later museum data (see following record) indicate possible locality error in original report (#53 for #54).

TABLE 2. (Continued)

Key to acronyms and symbols used in Table 2

ANSP - Academy of Natural Sciences of Philadelphia
FWS - U.S. Fish & Wildlife Service
USAO - University of Science and Arts of Oklahoma
< - Less than
+ - Unspecified fractional distance
± - Collector not present during all of multiple locality visits represented in record.

the portion of the Kiamichi River known to be inhabited by the species in recent times to 141 km (88 mi). In addition, it may be noted that between 1990 and the present, the FWS (unpublished data) salvaged a small number of empty shells of *A. wheeleri* and examined a few living individuals, all within the range identified by the researchers cited above, primarily at known sites on the Kiamichi River.

Meier and Vaughn (1998) surveyed for mussels and fish at 30 localities on 23 tributary streams of the Kiamichi River, using methods very similar to those employed by Vaughn *et al.* (1993). Their study resulted partly from recent public interest into whether such tributaries offered additional, as yet unknown habitat for the Ouachita rock pocketbook, in which case the river's overall population would be larger than estimated using habitat in the mainstem alone. They found no evidence of *A. wheeleri*, though they reported the FWS's 1997 discovery of an unweathered empty shell in Jackfork Creek downstream from Sardis Dam. Despite that latter discovery, the archaeological record reported by Bogan and Bogan (1983), and recovery of empty shells from Red River tributaries in Texas (see below), biologists have consistently concluded that the species is primarily adapted to large stream environments.

Clarke (1987) estimated the total Kiamichi River population as ranging from 100 to 1,000 individuals, based on his 50-mi figure, an estimate of 1,000 to 5,000 square meters (m^2) of habitat/river mile, and an average density of 0.002 to 0.004 individuals/m^2 in suitable habitat. Mehlhop and Miller (1989) estimated the Kiamichi River population to be just above 1,000 individuals (1,049), based on a documented range of 79.5 river mi, a measure of 88% (69.8 mi) of that as providing potential habitat, and an average density of 15 individuals/mi of potential habitat. Vaughn *et al.* (1993) calculated a mean density of *A. wheeleri* in occupied habitat as 0.27 individuals/m^2, but provided no new estimates of habitat availability or total size of the Kiamichi River population. The substantial difference between density estimates by Clarke (1987) and Vaughn *et al.* (1993) is due to differences between what those authors considered to be suitable and occupied habitat. Consequently, the two estimates should not be compared as indicating the temporal trend in a single parameter. The proportions of available habitat and individual density estimated by Clarke (1987) and Mehlhop and Miller (1989), if assumed still valid and applicable to the expanded range documented by Vaughn (*in litt.* 1994), would indicate a Kiamichi River population falling somewhere between 176 and 1,760 individuals.

Gordon and Harris (1983) collected relict shells of the Ouachita rock pocketbook from the Little River in Arkansas, just west of Arkansas Highway 41 and 6.4 km (4.0 mi) northwest of U.S. Highway 59/71, both sites located along the boundary between Little River County and Sevier County. Clarke (1987) found a small number of live individuals in a 1-km (0.7-mi) reach of the Little River running east from the Oklahoma-Arkansas state line, Little River-Sevier counties. He believed the species might exist through a defined section of about 8 river km (5 mi) extending east from the state line (a section the FWS estimates as closer to 7.25 km, or 4.5 mi). Clarke (1987) estimated the Little River population to be less than 100 individuals. In the Arkansas portion of their survey, Vaughn *et al.* (1995) found an *A. wheeleri* shell approximately 6.5 km (4 mi) east of the Oklahoma-Arkansas state line, Little River and Sevier counties, in 1994.

Clarke (1987) also surveyed the Little River in Oklahoma, but found no evidence of *A. wheeleri* there. Mather (pers. comm. 1993, *in litt.* 2001) and Bergmann found shells of the species in the Little River downstream of Pine Creek Reservoir, McCurtain County, Oklahoma, in 1991. Follow-up surveys in 1992 and 1993 produced additional shells from the same river section, from near Wright City to near Garvin, Oklahoma (Vaughn 1994, Mather *in litt.* 2001). Although most of the Oklahoma shells were weathered, one collected in each of 1991 and 1993 appeared to be from Ouachita rock pocketbooks that had died relatively recently. In 1994, Vaughn *et al.* (1995) discovered living *A. wheeleri* in the Little River section between U.S. Highway 70 and the Mountain Fork River confluence, in McCurtain County. They also found relict shells downstream of the Mountain Fork River, in both Oklahoma and Arkansas. An occurrence reported by Vaughn and Taylor (1999) likely represents one of the 1994 captures. For an inhabited Little River locality, Vaughn and Taylor (1999) calculated a standardized abundance measure for *A. wheeleri* of 0.7 individuals found/hour searching.

The recent occurrence of the Ouachita rock pocketbook in the Little River is less easily interpreted than in the Kiamichi River, because of the former river being affected to a greater extent by factors detrimental to stream fauna. No recent records exist for a 25-km (15.5-mi) section between Gordon and Harris's (1993) station west of U.S. 59 and White Cliffs. All recent records would suggest that the species exhibits a range of approximately 153 km (95 mi) in the Little River. However, significant parts of that range appear to be unsuitable for *A. wheeleri*, at least intermittently. In particular, the river segment between entry of the Rolling Fork River and the lowermost Little River locality has produced only fairly dated records of relict shells, and appears to be degraded by multiple, persistent factors (discussed later under Reasons for Listing/Threats). By excluding that segment, the overall recent range of *A. wheeleri* in the Little River may be estimated more accurately as approximately 111 km (69 mi). Portions of even that reduced distance lack suitable habitat due to degradation, and high quality conditions for the species may prevail in only a limited section (24 km/15mi) upstream of the Mountain Fork River confluence.

In 1992, Joseph Bergman found a Ouachita rock pocketbook shell in Pine Creek, a tributary entering the Red River near the mouth of the Kiamichi River, Lamar County, Texas (Mather pers. comm. 1993, Howells *et al.* 1996, 1997). In 1993, Mather and Bergmann found a second specimen in Sanders Creek, the next large Red River tributary in Texas upstream from Pine Creek, also in Lamar County (R.G. Howells, Texas Parks and Wildlife Department, *in litt.* 1994, Howells *et al.* 1996, 1997).

In a review of rare mollusks from Texas and Oklahoma, Landye (1980) listed the Ouachita rock pocketbook from the Kiamichi River of Oklahoma, plus the Little and Ouachita rivers of Arkansas. Landye (1980) did not find the species during limited field surveys performed as part of his survey. In a review of Oklahoma mussels, Branson (1983) reported the Ouachita rock pocketbook from the Kiamichi River in Oklahoma and Old River in Arkansas, based on previously published records and one specimen collected by Stansbery in 1971. In a review of Arkansas mussels, Harris and Gordon (1990) reported the Ouachita rock pocketbook from the Little River in Arkansas, the Kiamichi River in Oklahoma, and formerly from the Ouachita River. In the most recent assessment of Arkansas mussels, Harris *et al.* (1997) stated that *A. wheeleri* remains extremely rare.

Based on available data, the only known substantial population of Ouachita rock pocketbook mussels exists in the Kiamichi River of Oklahoma, upstream of Hugo Reservoir. A smaller, stressed population exists in the Little River between Wright City, Oklahoma, and the river's confluence with the Rolling Fork River in Arkansas. A diffuse, poorly known population continues to exist in the Ouachita River in Arkansas. Limited numbers of individuals appear to survive sporadically in tributary streams, such as Pine and Sanders creeks (Texas tributaries of the Red River) and Jackfork Creek. Many other localities in waters of the region have been surveyed without finding further evidence of *A. wheeleri* (e.g., see sources already cited, plus

Harris 1994, Mather and Bergmann 1994, Vaughn 1996a,b, 1997a, 2000, Vaughn *et al.* 1994a,b, Vaughn and Spooner 2000, Vidrine 1993, and White 1977). Nevertheless, continued survey work using current techniques is needed in less well-known systems to reveal whether the Ouachita rock pocketbook exists (or has existed) in additional populations, or occurs only sporadically outside the primary stream reaches where it is known to occur. Given the extent of past malacological surveys, any newly discovered populations are apt to be small, and the Kiamichi River population is likely to remain the sole viable population existing at this time.

Habitat/Ecosystem

Wheeler (1918) described the type locality of the Ouachita rock pocketbook as an oxbow lake, a former channel of the Ouachita River, still connected to the river by a small creek that did not appear to dry up in summer. From the mouth of the oxbow (located in a dense swamp) and for a mile or more upstream, the oxbow was described as, "deep and rather wide, with a very sluggish current." That habitat reportedly contained the largest Ouachita rock pocketbook individuals. Young individuals were found in shallow waters over sand bars and muddy bottoms; muddy river margins with little or no current were reportedly preferred. Approximately 41 other mussel taxa were indicated by Wheeler (1918) as also inhabiting the Old River locality, including very large specimens of the flat floater, *Anodonta suborbiculata*.

Isely (1925) collected a single Ouachita rock pocketbook from the Kiamichi River. The habitat type was categorized as a side channel/river bend with mud bottom, water 2-3 feet deep, and no current. In another portion of his paper, he described collecting the *A. wheeleri* specimen from a mud bank. Isely (1925) reported 21 other mussel species from the Kiamichi River at the Tuskahoma locality, including 13 other species that shared the side channel/river bend habitat.

Clarke (1987) described typical Ouachita rock pocketbook habitat as muddy coves or backwaters adjacent to riffles, or at least close to areas of moderate to rapid current. Clarke (1987) found the species in such habitats in the Kiamichi and Little rivers, guided by an observation by C.M. Mather that the species inhabited such sites. Number of other mussel species found at localities inhabited by *A. wheeleri*, with/without including shell evidence, reached as high as 21/13 species in the Kiamichi River and 12/11 species in the Little River. As mentioned earlier, Clarke (1987) estimated the amount of suitable *A. wheeleri* habitat present in the Kiamichi River as ranging between 1,000 and 5,000 m^2/linear mi, for the section he surveyed.

Mehlhop and Miller (1989) suggested that early survey efforts were restricted to shallow water habitats that could be easily hand-searched by waders. More recently, scuba use has increased for studying freshwater mussels and allowed effective sampling of deeper water habitats. In studying the Kiamichi River population, Mehlhop and Miller (1989) employed scuba gear and found that Ouachita rock pocketbooks also inhabited deeper pools in the river. Deep pools provided more abundant habitat in the river than backwaters, side channels, or other shallow areas. Number of other mussel species found by Mehlhop and Miller (1989) at localities inhabited by *A. wheeleri* reached as high as 16/14, depending on whether shell evidence was included/excluded. As mentioned earlier, Mehlhop and Miller (1989) estimated that 88% of the documented range in the Kiamichi River, or 69.8 river mi (112 km), constituted potential habitat for the species.

Studies of the Kiamichi River population by Vaughn and coworkers (Vaughn *et al.* 1993, Vaughn and Pyron 1995) included greater efforts than previously made to measure and analyze relationships between occurrence/abundance of *A. wheeleri*, associated mussel species, and various habitat parameters. Those studies found that Ouachita rock pocketbooks showed no preference between riverine pools and backwaters, but inhabited certain of these sharing five characteristics: (1) an abundant and diverse assemblage of mussels; (2) stable bottom substrata containing adequate amounts of fine gravel/coarse sand; (3) low (but not stagnant) summer-to-fall current velocities; (4) low siltation; and (5) proximity to tributaries, emergent vegetation, riffles, and gravel bars. Other measured parameters (water temperature, conductivity, dissolved oxygen, and pH) did not vary significantly among sites. Vaughn *et al.* (1993) and Vaughn and Pyron (1995) further described large mussel beds or shoals as key to the distribution of *A. wheeleri* in the Kiamichi River. Such shoals provided an optimal habitat in which many mussel species thrived. These shoals usually contained both pool and backwater areas, had significant gravel bar development with accompanying vegetation, were adjacent to major riffles, and were close (<0.25 mi) to tributary inflows. Those workers concluded that Ouachita rock pocketbooks cannot survive in less than optimal habitat for stream mussels.

Vaughn and Pyron (1995) developed a discriminant function model for predicting *A. wheeleri* occurrence, based on mussel species richness, depth, presence/absence of emergent vegetation, and habitat type. In that analysis, mussel species richness proved to be the best single predictor of *A. wheeleri* occurrence in the Kiamichi River.

In Vaughn's studies, localities inhabited by the Ouachita rock pocketbook were found to be inhabited by 11-19 other mussel species, as indicated by living individuals. Those sites exhibited a significantly greater number of mussel species, on average, than did sites lacking *A. wheeleri*. Based on abundance correlations, the species most positively associated with *A. wheeleri* was a mapleleaf, *Quadrula quadrula/apiculata*, followed by the washboard, *Megalonaias nervosa*, and the butterfly, *Ellipsaria lineolata*. Though absent or undetected at many sites, at confirmed sites the Ouachita rock pocketbook occurred at relative abundances of 0.2% to 0.7% (Vaughn *et al.* 1993, Vaughn and Pyron 1995). This and a density measurement of 0.27 individuals/m^2 indicated quantitatively the limited abundance attained by the species where it manages to survive.

Most recently, Posey *et al.* (1996) found a single live *A. wheeleri* mid-channel in a 2,600-m^2 Ouachita River mussel bed exhibiting gravel, gravel/sand, and sand substrates; 5- to 7-meter (m) water depths; and a 50-m mean river width. Posey *et al.* (1996) identified 21 other mussel species in the bed with *A. wheeleri*.

Vaughn *et al.* (1993) did not associate Ouachita rock pocketbooks with muddy or silty substrates, an observation that differs from the historical characterizations of Wheeler (1918), Isely (1925), and Clarke (1987). There are multiple possible explanations for this. As has been noted, some backwaters are relatively easy habitats to search and may have been sampled preferentially by early surveyors (Mehlhop and Miller 1989, Vaughn and Pyron 1995). However, it is apparent that the preceding workers recognized and surveyed habitats beyond backwaters. Different interpretations of substrate classes are possible, although discussions by the earlier authors indicate clear distinctions among sand, silt, and clay types. Different methods could be partly responsible, e.g., Vaughn's procedure used excavated, sieved substrate samples, while preceding workers might have used a visual approach, which could have favored superficial deposits. During low flow conditions associated with most stream surveys, substrates of diverse compositions can become coated with seasonal and proportionally minor silt layers. Still, some associated species reported in historical accounts (e.g., *Anodonta suborbiculata*) are considered adapted to muddy habitats (Oesch 1984, Harris and Gordon 1990). This suggests additional possibilities, such as changes in riverine conditions over time (e.g., as in Gammon and Reidy 1981, Turner and Rabalais 1991), and an incomplete understanding of the habitat relations of *A. wheeleri* across its range.

Degrees and aspects of habitat stability most vital to the Ouachita rock pocketbook also remain insufficiently understood, given their probable importance. Relative stability of substrates seems linked to the occurrence of mussel species in general (Vannote and Minshall 1982, Stern 1983, Young and Williams 1983, Strayer and Ralley 1993, Di Maio and Corkum 1995, Johnson and Brown 2000) and *A. wheeleri* specifically (Vaughn *et al.* 1993). Yet, there must be limits to this effect because streams are naturally dynamic systems in which there are frequent movements of substrate materials and longer-term changes in channel form, even with minimal human disturbance (Leopold *et al.* 1964, Allan 1995). Mehlhop and Miller (1989) observed that many Kiamichi River backwater areas visible in aerial photographs $\leq$10 years old shifted in location or disappeared through seasonal flooding. Vaughn *et al.* (1993) and Vaughn and Pyron (1995) also reported shifting of sediments between a backwater and pool inhabited by *A. wheeleri*. Certain low to intermediate levels and forms of stability may be most conducive to occurrence of many species, including rare forms (Death and Winterbourne 1995).

Closely related to stability are aspects of flow, considering that most movements of substrate materials appear associated with flood flows and abrupt changes in flow. Flows also can affect other processes such as delivery of oxygen and food items to mussels, removal of wastes, transport and concentration of sperm cells, sustained immersion of juveniles and adults, protection from heat stress, and formation of stream habitats. In the case of some mussel species and environments, such relationships have even been studied to varying degrees (Vannote and Minshall 1982, Salmon and Green 1983, Hartfield and Ebert 1986, Payne and Miller 1987, Di Maio and Corkum 1995, Layzer and Madison 1995, Tippit *et al.* 1997, U.S. Fish and Wildlife Service 1997b, Strayer 1999b, Payne and Miller 2000, Gore *et al.* 2001, Hardison and Layzer 2001). Several of these studies have led to indications that complex hydraulic variables and relationships offer significant potential for explaining local distributions of mussels and mussel habitats. In the case of the Ouachita rock pocketbook, however, the complexities involved are not known to an extent that is useful to many flow management decisions. In addition, native stream fish communities have shown adaptations to flooding and other elements of natural flow regimes (Ross and Baker 1983, Wootton *et al.* 1996, Poff *et al.* 1997), raising the possibility that the host fish for *A. wheeleri* might be affected by flow modifications. Consequently, significant relationships between stream flows and survival of the Ouachita rock pocketbook need further study and definition for specific waterbodies inhabited by the species. Abilities to reduce flood flows with impoundments, in an interest of increasing habitat stability (as has been suggested by some agencies), might not produce a net benefit when all effects are considered.

Additional study is needed of habitat requirements of the Ouachita rock pocketbook. One limitation of the studies by Vaughn *et al.* (1993) is that all sites used were known recent localities of *A. wheeleri*; thus, their evaluations examined fine distinctions among these rather than a broader contrast between suitable and unsuitable sites. Furthermore, even those workers faced inevitable constraints in regards to range of parameters examined, study intensity, and scale, and recognized that certain habitat dynamics were beyond the scope of their investigation. The characteristic rarity of the species adds to the difficulty of determining its habitat relationships. There remain apparently significant but inadequately understood factors affecting the restricted distribution of the Ouachita rock pocketbook, such as ones limiting occurrence outside certain sized streams. The Little River above Pine Creek Reservoir appears to be too small to support *A. wheeleri* (Clarke 1987, Vaughn *et al.* 1994a), as are many tributary streams, whereas the largest (most downstream) locality found thus far is that of Posey *et al.* (1996). Incompletely deciphered influences include drainage restrictions and other geographic, biological, environmental, and historical processes (Johnson 1980, Watters 1992, 1996, Strayer 1993, Vaughn 1997c, Haag and Warren 1998, Vaughn and Taylor 2000, Vaughn and Hakenkamp 2001). From a recovery standpoint, knowledge is needed of the most significant factors, sufficient to guide key management decisions.

Life History/Ecology

The Ouachita rock pocketbook's life cycle is unknown; however, it is most likely similar to that of other unionid mussels. Reproductive anatomy is likely similar to other members of the subfamily Anodontinae, as discussed by Ortmann (1912). Facultative hermaphroditism (ability of individual mussels to develop both male and female reproductive organs) has been suggested, along with other mechanisms, as a potential reproductive adaptation in *A. wheeleri* (Vaughn 1997b) but remains speculative.

Johnson (1980) designated the species as bradytictic (a winter breeder or long-term breeder), based on Wheeler's (1918) description of the breeding season as winter. Wheeler's conclusion is likely to have been based on unsuccessful efforts to find gravid females at inhabited localities, visited outside of winter, rather than any positive evidence. Clarke (1987) and Vaughn (1997b) predicted the Ouachita rock pocketbook to be a long-term breeder based on the condition seen in *Arcidens confragosus*, and other members of the mussel tribe Alasmidontini. *A. confragosus* is recorded as becoming gravid in September and exhibiting active glochidia (larvae) from January into March (Baker 1928, Clarke 1981). Vaughn *et al.* (1993) examined some *A. wheeleri* on-site (field work conducted between June and October) and retained in an artificial stream four individuals captured in September, one for nearly six months. None of these individuals were found to be gravid. No data are known that demonstrate the actual timing or duration of reproductive phases in the Ouachita rock pocketbook.

Nothing has been published describing the Ouachita rock pocketbook's glochidium. Based on related species, Clarke (1987) predicted that Ouachita rock pocketbook glochidia would possess stylets (hooks) used to attach to fish fins, tails, or scales. Vaughn *et al.* (1993) and Vaughn and Pyron (1995) noted that the stylets would likely be covered by microstylets and the glochidial shell should be asymmetrical in profile. Vaughn *et al.* (1993) collected general glochidial samples using drift nets and by dissecting the gills of fish from the Kiamichi River; their preserved samples were not processed to the point of identifying constituent species.

The natural fish host(s) of the Ouachita rock pocketbook remain(s) unknown. Nearly all unionid mussel species must parasitize fish to transform from glochidium to juvenile, and many can successfully parasitize only one to a few fish species (Lefevre and Curtis 1912, Coker *et al.* 1922). This narrow dependency on specific host fish is one of the main factors contributing to the high sensitivity of unionid mussels to environmental disturbance (Bogan 1993, Neves *et al.* 1997). Fish species that share the same natural distribution and habitat preference as the Ouachita rock pocketbook, and fish hosts for closely related species, likely include the host(s) for *A. wheeleri*. For the closest living relative, *A. confragosus*, known fish hosts include the American eel *Anguilla rostrata*, gizzard shad *Dorosoma cepedianum*, rock bass *Ambloplites* *rupestris*, white crappie *Pomoxis annularis*, and freshwater drum *Aplodinotus grunniens* (Surber 1913, Wilson 1916). In an attempt to identify strong candidates for host species, Vaughn *et al.* (1993) analyzed fish-mussel associations, and found positive correlations between *A. wheeleri* and nine species, led by the redfin shiner *Lythrurus umbratilis,* the channel darter *Percina copelandi,* and the rocky shiner *Notropis suttkusi* (at the time referred to as *N. rubellus* or *N. sp.*).

Vaughn (1997b) examined techniques used to study mussel reproduction and recommended particular approaches for investigating the reproductive biology of the Ouachita rock pocketbook. Her recommendations included additional fish species warranting evaluation as potential hosts and mussel species most appropriate as surrogates for *A. wheeleri* in reproductive research.

Mehlhop and Miller (1989) and Vaughn *et al.* (1993) were the first workers to analyze size/age distributions among a population of Ouachita rock pocketbooks using data from a significant number of individuals. Both research teams found the population dominated by adults well past juvenile stages, e.g., at least 15 years old. Similar findings are not uncommon among studies of other mussel species, produced by both natural characteristics of mussel populations and relatively low detection rates of juveniles. However, concerns have been expressed that many such cases reflect aging populations of adults in which adequate reproduction and recruitment of young are no longer occurring, due to environmental modifications (McMahon 1991).

Reasons for Listing/Threats

Impoundment, channelization, and water quality degradation have been identified as principal factors causing the decline of the Ouachita rock pocketbook (Clarke 1987, Mehlhop and Miller 1989, Martinez and Jahrsdoerfer 1991). Those same factors have been associated with declines of many freshwater mussel species and communities (e.g., Coker 1914, Ellis 1936, Stansbery 1970, Starnes and Bogan 1988, Bogan 1993, Williams *et al.* 1993). Most reports of mussel declines and responsible factors have been based on observation and inference, with little cause and effect data. This is partly because most environmental modifications are made without detailed assessments of impacts, and partly because diagnostic analyses usually were not available or appropriate to the scale and intent of standard studies performed on mussels. It also can be attributed to the typically complex nature of most environmental and biological impacts (Allan and Flecker 1993, Watters 2000). The following paragraph illustrates some of the complexities involved.

When impounded, stream environments undergo many changes, such as decreased water velocities, temperatures, and dissolved oxygen levels; and increased levels of carbon dioxide, nutrients, and sediment deposition, including a greater proportion of compounds in chemically reduced form. Many of these changes can contribute to reductions in mussel diversity and productivity, although the relative contribution of each may be difficult to distinguish (or considered unimportant, as long as the sum of changes proves significant). Limnological studies strongly indicate that adverse effects of impoundment (and channelization) on aquatic life occur partly from changes in water quality produced by those modifications. Thus, the two factors of impoundment/channelization and water quality are not strictly separable. In addition, certain types of pollution produce water quality changes that resemble, and may augment, changes produced by impoundment and channelization. Furthermore, although some forms of pollution are potent enough to singularly impact mussel communities, actual instances of pollution more commonly involve multiple sources and processes that are complex, interrelated, and difficult to separate.

In spite of complexities, significant progress has been made in clarifying the influence of natural and anthropogenic factors on freshwater environments, and the effects of various physical and chemical conditions on mussels, including some of the underlying physiological mechanisms (Fuller 1974, McMahon 1991). Experimental studies have produced evidence generally supporting incompletely documented reports of mussel declines and their implied causes (e.g., see references cited below in separate discussions of threats). As highly influential factors, impoundment, channelization, and water quality degradation are recognized as major modifications that embrace many smaller modifications and reactions. Few native freshwater mussels are adapted to live in environmental conditions produced by such major modifications. Commonly observed evidence of effects in actual environments include reduced communities of only tolerant species, dead mussels or shells positioned naturally in the substrate, or populations containing no or reduced numbers of juvenile mussels.

Continued growth and activity of human populations portend that these major factors, at least impoundment construction and water quality degradation, will continue and expand in influence. Thus, they pose significant threats for further declines of native mussels such as the Ouachita rock pocketbook. Within portions of this species' range, recent proposals to withdraw and transport large quantities of water for human consumption have raised an additional threat, related essentially to reservoir development, and with similar bearings on stream organisms. Moreover, various other factors, mostly secondary in significance, have been identified as potential future threats to *A. wheeleri*.

Efforts to analyze impacts and identify conditions needed by the Ouachita rock pocketbook benefit from a number of information sources and technical abilities presently available. The U.S. Geological Survey, U.S. Army Corps of Engineers, and other agencies monitor flow rates and a range of water quality parameters for all stream systems comprising the natural range of *A. wheeleri*. That information allows comparison of conditions between areas still inhabited by the Ouachita rock pocketbook and areas in which the species has declined or perished. A limited historical record and sophisticated models currently available also allow comparison between historical and present conditions in impacted areas. As with the hydrologic and water quality data, various agencies periodically record land features using aerial photography and satellite sensing. Such records provide another means of comparing conditions between times or areas of suitable habitat. Some studies have already been performed of recent land use patterns within the Kiamichi River, Little River, and upper Ouachita River basins. One further example involves researchers at the Oklahoma Natural Heritage Inventory, University of Oklahoma, which have maintained a significant track of research since the late 1980s into status and ecology of *A. wheeleri* and the mussel communities of Ouachita streams.

<u>Impoundment, channelization, and flow modification</u>

Some of the greatest impact on Ouachita rock pocketbook habitat throughout its natural range has been from construction and operation of impoundments for multiple purposes, i.e, flood control, water supply, water quality, hydroelectric power generation, navigation, recreation, and fish and wildlife management. Construction of impoundments can be deleterious to most native mussels in a number of ways, many of which are related to the siltation that accompanies impoundment (Coker 1914, Scruggs 1960, Bates 1962, Isom 1969, Neves *et al.* 1997, Watters 2000). The stream sections flooded directly are subject to many physical and chemical changes, among them (at the level of benthic habitats) increased depth, sediment deposition, and carbon dioxide concentrations; decreased flow velocities, illumination levels, average temperatures, dissolved oxygen concentrations, and pH; and lags in seasonal temperature changes (Neel 1963, Oesch 1984). Although some mussel species are tolerant and establish successful populations in impoundments (White and White 1977, Mather 1989, Howells *et al.* 2000), the large majority of species are not adapted to live in such conditions (Parmalee *et al.* 1982, Williams *et al.* 1992, Parmalee and Hughes 1993, Blalock and Sickel 1996).

In addition to affecting the impounded section, reservoirs modify river habitats downstream, typically altering flow and temperature regimes, erosion and deposition of sediments, and composition/transport of plankton and other organic materials (Baxter 1977, Williams and Wolman 1984, Ligon *et al.* 1995, Collier *et al.* 1996, Poff *et al.* 1997, Hadley and Emmett 1998). While wide ranges in these conditions may be normal for unimpounded streams, the variation produced downstream of dams frequently differs from natural variation in some critical respects, thus affecting suitability of the tailwater habitats for native species. The altered conditions tend to approach more natural states with increasing distance from the dams (Voelz and Ward 1991, Vaughn and Taylor 1999); however, within the altered zone, aquatic communities are invariably modified and depressed, and sensitive species may be eradicated (Fisher and LaVoy 1972, Suloway *et al.* 1981, Miller *et al.* 1984, Williams *et al.* 1992, Layzer *et al.* 1993, Heinricher and Layzer 1999, McMurray *et al.* 1999, Vaughn and Taylor 1999). Flow velocities and stream stages, for example, may be modified frequently or abruptly below dams. This can injure or strand many mussels, which generally have limited mobility (Vaughn *et al.* 1993, Layzer and Madison 1995). Where death is avoided by reimmersion, mussels exposed by stranding to frequent or prolonged temperature extremes still can experience excessive physiological stress and reduced reproductive potential (McMahon 1991).

In some cases, suitable conditions for stream mussel species have been maintained in downstream stream sections (Isom 1969, Dennis 1984), indicating that it is possible to mitigate adverse effects on tailwaters by implementing appropriate structural and operational measures. Available evidence shows, however, that the Ouachita rock pocketbook survives only in optimum stream mussel habitat (Vaughn *et al.* 1993, Vaughn and Pyron 1995, Vaughn and Taylor 1999). The extent to which such habitat can be restored below impoundments in its range is unknown. Finally, it should be recognized that impoundments exert negative effects on mussels surviving in upstream waters (and surviving populations in general), because the isolation produced by dams reduces their resilience to local declines and prevents genetic exchange with other populations.

Just as reservoirs can affect mussels directly within the reach of impoundment, in tailwaters and headwaters, in each of these areas they may affect distribution or behavior patterns of fish species that are required hosts for larvae of freshwater mussels (Hubbs and Pigg 1976, Swink and Jacobs 1983, Bain *et al.* 1988, Kinsolving and Bain 1993). Such effects could reduce or eliminate reproductive success of mussel populations dependent upon those fish.

Where channel modifications are made to provide for navigability by commercial watercraft, riverine habitats are degraded in additional ways (Clark 1976, Coon *et al.* 1977, Harris and Gordon 1987, Neves *et al.* 1997, Watters 2000). The channelization and dredging involved in creating and maintaining navigable channels are especially deleterious to native mussels. The most obvious means is from the actual removal of mussels and their habitat by the cutter head of the dredge. In addition, dredging and channelization directly disturb and destabilize large quantities of sediments not removed, but left within the affected systems. For long periods afterwards, such sediments may remain largely in suspended states or as unstable substrate deposits. This effect is increased by other aspects of these projects, e.g., the bypassing of meanders with shortened channel segments; the removal of normal, established variations in width, depth, and slope of the stream channels; the removal of riparian vegetation; the creation of dredged spoil piles; and barge traffic. Periodic maintenance dredging ensures that channelized streams remain disturbed over time. Few freshwater mussels are adapted to live in such habitat. Like impoundment, channelization may affect distribution or behavior patterns of fish species that act as required hosts for larvae of freshwater mussels.

Withdrawals of large quantities of surface water often are combined with impoundments, generally because those structures provide places of storage until use of the water occurs. Withdrawals obviously reduce flows and quantity of aquatic habitat downstream of points of diversion, and may increase flows elsewhere, by wastewater returned to streams near points of use. Those reductions and increases in flow produce physical, chemical, and biological changes, essentially like those produced with stream flow alterations below dams. Where portions of stream channels are incorporated into the means for delivering flows for human use (e.g., rather than total reliance on pipelines or artificial canals), associated effects become less related to overall quantities of flow and more related to timing of discharge and water quality issues. Water diversions that reach a scale of transferring flows between unrelated basins exhibit an additional potential to introduce species outside of their native ranges.

Numerous large impoundments have been constructed within the natural range of the Ouachita rock pocketbook, or are close enough to the range to potentially affect habitat sites used by the species (Oklahoma Water Resources Board 1990, U.S. Army Corps of Engineers 1989). On the Kiamichi River, Hugo Reservoir was impounded on the mainstem in 1974, and Sardis Reservoir on Jackfork Creek, a main tributary of the river, in 1983. Another impoundment, Tuskahoma Reservoir, is authorized for construction on the mainstem of the Kiamichi River near Albion, Pushmataha County, but has not been built. On the Little River mainstem, Pine Creek Reservoir and Millwood Reservoir were impounded in 1969 and 1966, respectively. Reservoirs on larger tributaries of the Little River (and years of first impoundment) include Broken Bow Reservoir on the Mountain Fork River (1968), DeQueen Reservoir on the Rolling Fork River (1977), Gillham Reservoir on the Cossatot River (1975), and Dierks Reservoir on the Saline River (1975). The Ouachita River mainstem has been impounded in Arkansas to form Lake Ouachita (1953), Lake Hamilton (1932), and Lake Catherine (1924), and by H.K. Thatcher Lock and Dam (1984) and Felsenthal Lock and Dam (1984). The Caddo River and Little Missouri River (large tributaries of the upper Ouachita River) have been impounded to form Degray Lake (1972) and Lake Greeson (1950).

Many of these impoundments include facilities for hydroelectric generation, which usually increase reservoir-related impacts, because of sharper fluctuations in water levels and preferences to draw water from deeper depths. In addition, following early experiments with establishing a trout fishery in Broken Bow Reservoir, a put-and-take trout fishery was established in the Mountain Fork River downstream of the dam beginning in 1989. Reservoir releases from that dam, tailored largely to serve hydroelectric generation, are modified further in attempts to support the trout fishery by producing cool tailwater temperatures. Interest exists to achieve even lower tailwater temperatures extended over a greater length of stream (conditions needed for more successful development of the fishery), by modifying the dam and its operations in additional ways.

Development of the Ouachita River for navigation was first authorized more than 100 years ago and consisted of channel clearing and snagging from Arkadelphia to the mouth of the Black River. Lock and dam developments in 1926 provided a 6.5-foot-deep navigable channel from the mouth of the Black River to Camden, Arkansas. The project was modified to provide a 9-foot navigable channel to Camden by construction of four new locks and dams, including the two in Arkansas mentioned above. The project includes 11 cutoffs and 14 bend widenings that have not yet been performed.

Environmental changes related to impoundment and channelization have been reported for the river sections historically inhabited by Ouachita rock pocketbooks. Survey results indicate that *A. wheeleri* is sensitive to those changes. Clarke (1987) noted that he and other workers had recently failed to find living Ouachita rock pocketbooks in the Ouachita River, and that the river was now impacted by several hydroelectric dams and artificial lakes.

Clarke (1987) reported the Little River to be strongly influenced by cold hypolimnetic discharges from Pine Creek Reservoir, for about 30 mi downstream from the dam (all within Oklahoma). Extensive former beds containing old shells of many mussel species, and very few live individuals, occurred in that segment. Vaughn (1994) reported very similar conditions in the Little River, from just downstream of Pine Creek Reservoir to Garvin, Oklahoma. Shells immediately downstream from the reservoir were highly corroded and coated with an orange rust-like substance. Vaughn (1994) noted cold water releases from the reservoir as one of several disturbances present in the affected section. Following further investigation, Vaughn and Taylor (1999) reported a severe, extended depression of mussel populations downstream of Pine Creek Dam. No live mussels were found at three locales closest below the dam. Mussel species richness and abundance did not recover significantly until 20 km downstream and did not peak until 53 km downstream. Vaughn and Taylor (1999) identified coldwater releases from Pine Creek Reservoir as undoubtedly affecting mussel populations of the Little River, possibly in conjunction with flow modifications. Although they identified other disturbances as well, only the impoundment-related alterations corresponded closely with the predominant trend and scale of impacts observed on the mussel community.

Clarke (1987) observed no clear deleterious effects that he could attribute to releases from Broken Bow Reservoir, and measured an improvement in mussel diversity in the Little River near its confluence with the Mountain Fork River. However, he noted unexpectedly cold water in the Mountain Fork River, and limited effects (dead mussel beds mid-stream, live mussels concentrated near tributary inflows, and $\geq$20 years' reduced growth in threeridge specimens) in the Little River below the two streams' confluence. Furthermore, Clarke (1987) stated that a potential exists for very serious damage to mussels from Broken Bow Reservoir, even to the point of eliminating the Little River Ouachita rock pocketbook population. The "favorable" conditions he saw near the Mountain Fork River continued downstream for several miles, whereupon mussel diversity dropped again (attributed to pollution carried by the Rolling Fork River). Diversity began to recover a second time, only to reach Millwood Reservoir, where conditions were deemed unsuitable for the Ouachita rock pocketbook and other riverine mussels (Clarke 1987). In more recent years, Vaughn and Taylor (1999) found mussel species richness and abundance declined dramatically downstream of the Mountain Fork River confluence, and showed only meager returns of species (not abundance) in the 15-km section surveyed. They judged summer water releases from Broken Bow Reservoir as being colder than the receiving waters, to the point of undoubtedly affecting mussel populations downstream. Despite current degradation, the discovery of empty Ouachita rock pocketbook shells at several Little River sites and the small living population in Oklahoma and Arkansas demonstrate that the river once provided suitable habitat for the species.

The lower Kiamichi River includes a portion flooded by Hugo Reservoir and an affected section between the reservoir and the Red River, neither of which now support the Ouachita rock pocketbook (Clarke 1987). One historical record (Valentine and Stansbery 1971) indicates that *A. wheeleri* inhabited at least one river site subsequently flooded by the reservoir. Upstream of Hugo Reservoir, Clarke (1987) observed no negative effects on the mainstem population from releases out of Sardis Reservoir through Jackfork Creek. Mehlhop and Miller (1989) believed, however, that Sardis Reservoir releases had altered water quality in the river downstream of Jackfork Creek, specifically by reducing temperatures and altering flows. Mehlhop and Miller (1989) suggested that altered conditions could affect Ouachita rock pocketbooks in a number of ways, including reduced metabolic rate and growth, decreased nutrient supply, and altered availability of fish hosts for glochidia. The FWS (unpublished data) collected temperature data from Jackfork Creek and the Kiamichi River in 1997, and confirmed that releases from Sardis Reservoir significantly reduced summer temperatures downstream, at least within the creek.

In a comparison of former localities upstream and downstream of Jackfork Creek, Vaughn *et al.* (1993) and Vaughn and Pyron (1995) found *A. wheeleri* absent from some of the downstream localities and less abundant on average at the downstream sites. In view of many difficulties of directly evaluating reproduction by *A. wheeleri,* Vaughn *et al.* (1993) also examined drift densities of general mussel glochidia and size distributions of a surrogate species, *Amblema plicata*. They found lowest glochidial densities at the first two sites downstream of Jackfork Creek, though ample adults were present, and significantly greater numbers of young *A. plicata* upstream from Sardis versus downstream. Vaughn *et al.* (1993) and Vaughn and Pyron (1995) judged all of the live Ouachita rock pocketbooks they encountered in the Kiamichi River to have been produced prior to the filling of Sardis Reservoir in 1983. In their analysis of land use in the Kiamichi River watershed, Vaughn *et al.* (1993) concluded that Hugo and Sardis reservoirs constituted the most significant recent land use change to date.

Vaughn *et al.* (1993) directly observed large differences in water level and flow fluctuations between stations in the Kiamichi River immediately upstream and downstream of Sardis Reservoir. One visit to a downstream site appeared to coincide with a drastic drop in water levels, stranding >100 mussels and many fish in small warm pools (>35˚ C), where many were perishing. In September 2000, researchers encountered very low flows at a Kiamichi River locality downstream from Sardis Reservoir (C.C. Vaughn, pers.comm. 2000, Spooner and Vaughn 2000). Flows had declined to a point that many mussels had died or were distressed, resulting from high water temperatures and desiccation. *A. wheeleri* and the scaleshell mussel, *Leptodea leptodon* (at the time a proposed endangered species, final endangered status published October 9, 2001) were among the species represented in the kill. While an extended drought partly produced the low flow conditions, a lack of reservoir releases into Jackfork Creek (which contributes, on average, nearly 30% of the river flows at the point of confluence) unquestionably played a part as well. Upon a request from the FWS, the U.S. Army Corps of Engineers (CE) began special releases (5 cubic feet/second) from Sardis Reservoir, which relieved conditions in the mussel beds until later rains revived river flows. Thus, given normal operations, mussel habitats downstream from Sardis Reservoir may experience both excessive fluctuations in flows and prolonged flow reductions during critical periods.

Incidental to other work in the area from 1997 into 1999, the FWS (unpublished data) observed that the Kiamichi River channel immediately downstream of Jackfork Creek was greatly disturbed, exhibiting extensive bank erosion, an abrupt decrease in depth, and widespread burying of the former substratum under a thick layer of unstable sediments. Site conditions suggested that the channel modifications resulted largely from reservoir operations, i.e., frequent, sudden, and/or marked changes in flow, rather than from other factors (e.g., clearing of riparian forest) more widely dispersed along the river corridor. Finally, aside from any effects on the river mainstem, Sardis Reservoir has displaced and affected habitat in Jackfork Creek that might have been suitable for the Ouachita rock pocketbook.

Tuskahoma Reservoir, if constructed, would flood a large, likely critical portion of the extent of Kiamichi River now inhabited by the Ouachita rock pocketbook. Authorities have readily predicted that addition of the reservoir would eliminate the species from the flooded section (Clarke 1987, Mehlhop and Miller 1989). It is reasonable to presume that headwater and tailwater effects would extend impacts to the species beyond the flooded section, especially downstream, with a potential to negatively affect all or nearly all of the remaining Kiamichi River population. Because of its foreseeable impact on the only healthy population of the Ouachita rock pocketbook, Tuskahoma Reservoir constitutes a very serious threat to the species. The reservoir project is congressionally authorized, but no funds have been appropriated and the CE has suspended further planning at this time.

Numerous other potential water resource development projects, other than Tuskahoma Reservoir, have been proposed within the range of the Ouachita rock pocketbook. However, such projects have been discussed largely on a conceptual basis. None have had detailed information submitted for formal consideration by the FWS (at the time of this writing). An example of a project concept drawing significant recent attention centers around releasing water from Sardis Reservoir (in the realm of 150,000 acre-ft/year), passing it down the Kiamichi River channel to Hugo Reservoir, where it would be pumped via pipeline into the Trinity River basin of north Texas. Variations of that basic project include withdrawals of a comparable quantity of water from the Little River and Mountain Fork River, which would be piped and added to the Kiamichi River withdrawals. Impacts posed by the conceived water development projects vary greatly in relation to their size, location, and specific project features.

Impoundment, channelization, and flow modification may pose hazards to the Ouachita rock pocketbook beyond those already identified. Without knowing more of the life history and habitat requirements of the Ouachita rock pocketbook, the impact of these developments on the species cannot be fully determined. Because of the predominantly negative nature of known impacts, steps should be taken to answer additional key questions about *A. wheeleri* in the course of evaluating water development proposals within the species' range.

Water quality degradation

A variety of activities can degrade water quality, including point and nonpoint source pollution discharges, changes in the amount of stream shading, and other watershed alterations. Water quality degradation can be deleterious to native mussels in a number of ways (Isom 1969, Fuller 1974, Bates and Dennis 1978, Foster and Bates 1978, Horne and McIntosh 1979, Dennis 1981, Havlik and Marking 1987, McMahon 1991, Neves *et al.* 1997). Water quality is most obviously degraded for mussels by pollutants that are toxic or otherwise injurious to these organisms (e.g., Keller and Zam 1991, Jacobson *et al.* 1993). Water quality also is degraded by conditions that directly or indirectly deprive mussels of their normal biological needs, such as acceptable ranges of dissolved oxygen, nutrients, water temperatures, substrate consistency, and suitable hosts (Coker *et al.* 1922, Dimrock and Wright 1993, Sparks and Strayer 1998).

Although effects of pollution on freshwater mussels have been documented, relatively little data are available on tolerance limits of freshwater mussels to specific pollutants. Most work in this area, such as that by Foster and Bates (1978), has dealt with heavy metal concentrations. Havlik and Marking (1987) reviewed the effects of contaminants on naiad mollusks, including a large number of metals, pesticides, and other pollutants. They compiled toxic concentrations reported in other studies, and concluded that contaminants had reduced mussel density, range, and diversity. Silt is suggested to interfere with respiration, feeding, and/or reproduction due to irritation and clogging of mussel gills and siphons (Ellis 1936, Dennis 1984, Aldridge *et al.* 1987, Brim Box and Mossa 1999).

Extreme water quality conditions measured in mussel habitats can be misleading, because many mussels are able to detect certain adverse conditions, and may exclude them temporarily by retreating within their shells until conditions improve. However, exposure to such conditions on a frequent or prolonged basis can significantly interfere with feeding. Abilities to detect and exclude adverse conditions are incomplete, so that limited exposures often impact at least some members of any given mussel population. It is clear that most freshwater mussel species are not adapted to live in the degraded water quality conditions caused by unmitigated human activities. As in the case of impoundment and channelization, it is necessary also to consider the effect water quality may have on fish species that serve as hosts for mussel glochidia.

Considerable progress has been made assessing pollution sources and developing water quality management programs in states where the Ouachita rock pocketbook occurs. That progress, overseen by the U.S. Environmental Protection Agency and the states involved, has taken place largely through substantial funds made available under Section 208 and other sections of the Clean Water Act. Programs in place provide the means necessary to monitor instream quality, regulate point sources, and reduce nonpoint sources affecting the health and distribution of *A. wheeleri* populations. The upper Ouachita River in Arkansas has recently been described as having generally good and improving water quality, with elevated nutrients from a municipal source constituting the principal known source of continuing impairment. In Oklahoma, the Little River is considered to have water quality supportive of its beneficial uses, but threatened by silvicultural pesticides, atmospheric nutrients, acidity, high suspended solids, and siltation from unspecified sources. In Arkansas, water quality in the Little River continues to be impaired by several chronic problems, including three that degrade the Rolling Fork River: agricultural nonpoint sources, a Weyerhaeuser Superfund site, and the City of DeQueen. The Kiamichi River is considered to have water quality supportive of its beneficial uses, but threatened by acidity from the atmosphere and pastureland, nutrients from crop production, siltation from rangeland, and suspended solids from silviculture (Arkansas Department of Pollution Control and Ecology 1992, Oklahoma Department of Pollution Control 1992).

Habitat changes characteristic of water quality degradation have been reported for river reaches historically inhabited by the Ouachita rock pocketbook. Survey results indicate that *A. wheeleri* is a species sensitive to those changes. Gordon and Harris (1983) reported degraded conditions in both the Ouachita River and Little River in Arkansas, with organic eutrophication suggested as the probable cause. Water quality degradation appeared to be extensive in the main channel of the Ouachita River, where few live mussels were seen and shells of recently dead mussels were not frequently encountered. Evidence of Ouachita rock pocketbook inhabitation was limited to relict shell material at a single site. Clarke (1987) reported the Old River oxbow (the type locality) to be severely polluted and found no evidence of it being inhabited by any mussel species. He specifically noted the water exhibiting an oily surface film and other degradation attributed to a large trash dump extending into the oxbow.

In the section of Little River between Pine Creek Reservoir and U.S. Highway 70, Vaughn (1994) observed evidence of mussel kills, in-stream sedimentation, and surface films, and noted a mill discharge, a chicken processing plant discharge, other point source discharges, chicken farms, logging, gravel mining, cattle, and feral swine as non-reservoir related water quality disturbances present. Vaughn and Taylor (1999) elaborated on the effect of the "paper mill" [in reality a sawmill], attributing it with small-scale reductions in abundance and diversity that dissipated within 2 km. They also described sedimentation as patchy and occurring within all sections of the Little River that they sampled. In the Little River section between U.S. 70 and the Rolling Fork River confluence, Vaughn *et al.* (1995) observed evidence of mussel kills and in-stream sedimentation, and noted gravel mining, riparian clearing, and feral swine as potential sources of degradation. Clarke (1987) identified an inadequately treated sewage discharge by the City of Idabel in McCurtain County, Oklahoma, as a source of possible harm to a surviving population of the Ouachita rock pocketbook in the Little River. He also identified a gravel dredging operation in the Little River north of Goodwater, McCurtain County, as another source of potential harm to that population, presumably by water quality effects. In the Little River in Arkansas, Gordon and Harris (1983) found evidence of a recent catastrophic die-off of mussels, with many thousands of mussel shells found at most of the nine sites sampled. A thriving mussel fauna had been observed in 1979. Live mussels were encountered only in backwaters away from the main channel and in the river just upstream of Millwood Reservoir. Evidence of the Ouachita rock pocketbook was limited to relict shells at two sites, as previously stated. Clarke (1987) reported that mussel diversity dropped dramatically in the Little River in Arkansas, approximately five miles downstream from where the mussel community had largely recovered from effects caused by releases from Pine Creek Reservoir. He attributed the decline to pollution periodically entering the Little River from the Rolling Fork River. Vaughn *et al.* (1995) found no live mussels downstream from the Little River's confluence with the Rolling Fork River, and empty shells of only the Asian clam, *Corbicula fluminea*.

In regard to the Kiamichi River, Clarke (1987) stated that no significant municipal pollution was evident from Clayton, Oklahoma. Mehlhop and Miller (1989) described point source pollution affecting the Kiamichi River as low, and indefinite contributions from nonpoint sources. However, they identified a gravel mining site, a bridge construction site, and a proposed pipeline crossing as activities likely to impact nearby Ouachita rock pocketbooks by degrading water quality. In addition to existing activities, it has been predicted that any development of hydropower facilities at Sardis Reservoir would degrade conditions in the Kiamichi River.

Water quality degradation likely poses hazards to the Ouachita rock pocketbook beyond those that are already known. Without knowing more of the life history and habitat requirements of the Ouachita rock pocketbook, the impact of water quality degradation on the species cannot be fully determined for all parts of its range.

<u>Other factors</u>

Gravel excavation, construction of road and utility crossings, and vehicle/livestock activities within stream channels can impact mussels and mussel habitats directly, in addition to degrading water quality downstream (Brown and Curole 1997, Meador and Layher 1998, Jennings 2000, Watters 2000). Valentine and Stansbery (1971) reported a gravel dredging operation on the Kiamichi River in which many mussels were buried or crushed, at a site inhabited by the Ouachita rock pocketbook. Several local roadways cross the Kiamichi River at fords, used by vehicles ranging from all-terrain vehicles to logging trucks. Evidence indicates that some mussels are negatively impacted by large vehicles driven across the streambed or used to maintain the fords.

Beyond the channels, surrounding landscapes significantly influence stream environments, exerting effects on water quality, hydrology, and organic production. Changes in landscape condition and introduction of unmitigated human activities can dramatically degrade aquatic communities and habitats (Vaughn 1997a, Watters 2000). Although all portions of a watershed relate to the stream environment, in general, the greatest influence is produced by riparian zones that border stream channels. Because riparian zones can be affected by flow alterations and other stream modifications, potential exists for a compounding of effects between these environments. Indeed, many ecological interactions occur between streams and riparian zones (Morris and Corkum 1996), making the latter natural areas of focus in stream and mussel conservation. Vaughn *et al.* (1993) found the Kiamichi River watershed to maintain significant coverage by mature forest, but believed much of the forest was likely to differ from its original state. In addition, they observed many cut forest stands in various stages of regrowth and human developments concentrated along and near the river channel. Certain and Vaughn (1994) found very similar conditions in the Little River and Ouachita River watersheds.

Mehlhop and Miller (1989) identified the introduced Asian clam, *C. fluminea*, as a potential threat to the Ouachita rock pocketbook. *Corbicula* became established in the region in the mid-1970's (Britton and Murphy 1977, White and White 1977). Since then, it has become widely dispersed throughout area surface waters and is often abundant. To date, however, biologists working within the region have not reported evidence of Asian clams competing directly with native mussels or otherwise affecting them adversely. Studies elsewhere have produced mixed results, some indicating adverse effects on native mussels but others indicating none (Belanger *et al.* 1990, Leff *et al.* 1990, McMahon 1991, Strayer 1999a). However, the exotic zebra mussel, *Dreissena polymorpha*, may pose a serious biological threat to the Ouachita rock pocketbook. This small bivalve is environmentally adaptive and prolific, producing immense populations within most freshwater environments to which it is introduced. The zebra mussel has high dispersal capabilities, and has spread extensively within the U.S. since its introduction here in 1985 or 1986, including up the Arkansas River system into Arkansas and Oklahoma. However, it has not been reported from the Red River or Ouachita River systems, where *A. wheeleri* occurs. Zebra mussels secrete threads by which they attach to most firm underwater surfaces, including shells of native mussels. Although the ultimate biological impact cannot be predicted, evidence indicates these mussels will eventually infest most major North American drainages south of central Canada and will interfere with normal feeding and movements of native mussels, sufficient to seriously reduce native mussel populations (Strayer 1991 and 1999a, Neves *et al.* 1997, Ricciardi *et al.* 1998). Contaminated watercraft facilitate dispersal of zebra mussels; thus, existing and future impoundments and navigation pools (where most watercraft activity occurs) constitute the most likely centers from which zebra mussels might infest the range of the Ouachita rock pocketbook.

Wheeler (1918) reported that *A. wheeleri* was sometimes harvested by persons mistaking the species for *Quadrula pustulosa*. Vaughn *et al.* (1993) noted that commercial harvest of mussels was currently prohibited in the Kiamichi River, but felt such activity, if allowed, could pose a grave threat to *A. wheeleri*. Finally, over-collection for scientific or hobby purposes may have constituted a threat to the Ouachita rock pocketbook at one time. This possibility is suggested by the large number of *A. wheeleri* specimens collected from the Old River locality within a short span of years, and the subsequent lack of specimens from that locality (although the relative effect of over-collection versus pollution and other factors cannot be determined at this point). Current prohibitions against take of *A. wheeleri* and a greater appreciation of its endangered status should largely eliminate over-collection as a significant threat to the species.

Reduction and/or elimination of significant threats to the species and its habitat are necessary to achieve recovery. Three sections in this recovery plan, the *Narrative Outline for Recovery Actions*, *Recovery Actions Specifically Addressing Endangered Species Listing Factors* (Table 3), and the *Implementation Schedule*, detail a variety of actions (e.g., monitoring of threats, upgrading of water quality standards, and public outreach) that if implemented, will address the threats discussed above.

<u>Conservation Measures</u>

Since listing, a number of efforts have been made to help conserve the Ouachita rock pocketbook. A three-year study, funded through Section 6 of the Endangered Species Act, was completed regarding habitat use in the Kiamichi River. That study contributed much information regarding *A. wheeleri* occurrence in different river microhabitats. Movement, growth, survival, population fluctuations, and relative influence of water pollution and impoundment on mussel populations also were examined. Subsequent studies, funded primarily by the FWS, updated occurrence of the Ouachita rock pocketbook and threats to its existence within the Little River. Results of these various studies were reported by Vaughn (1994), Vaughn *et al.* (1993, 1994, 1995), Vaughn and Pyron (1995), and Vaughn and Taylor (1999), and are summarized in this plan in the preceding sections on distribution, habitat/ecosystem, life history/ecology, and reasons for listing/threats. As a part of these studies and through supplemental funds (Certain and Vaughn 1994), land uses were assessed within portions of the Kiamichi River, Little River, and Ouachita River basins. Other post-listing studies funded through Section 6 or discretionary FWS funds include a survey of Kiamichi River tributaries (Meier and Vaughn 1998) and planning for studies of reproduction in *A. wheeleri* (Vaughn 1997b). Most recently, Region 4 and the Arkansas Field Office of the FWS have funded a research project to investigate suitable host fish species for the Ouachita rock pocketbook and collect other new information on reproduction, habitat, and populations of the species in Arkansas and Oklahoma (Susan Rogers, FWS, *in litt.* 2001). That project is being performed by Arkansas State University.

The U.S. Forest Service (FS) has funded a number of surveys to ascertain the possible occurrence of the Ouachita rock pocketbook on and near FS lands (Vaughn *et al.* 1994b, Vaughn 1996a, Vaughn and Spooner 2000). Although those surveys did not discover additional localities of the species, they answered questions of possible occurrence in several streams targeted for survey work in the draft recovery plan. The FS also conducted a substantial assessment of aquatic resource information applicable to the Ozark and Ouachita Highlands (Bell *et al.* 1999). Mussel species comprised one representative resource used in that assessment, which presents analyses useful to continuing research and management in the region.

As part of a memorandum of understanding with the FWS, the Oklahoma Department of Environmental Quality (ODEQ) agreed to recognize a FWS list of Aquatic Resources of Concern in Oklahoma. The list includes the Kiamichi River and Little River drainages in southeast Oklahoma, based on their inhabitation by the Ouachita rock pocketbook and other federally-listed species. The memorandum provides for the FWS to receive special notification of proposed discharge permit actions pending before the ODEQ, where those actions involve waters listed as Aquatic Resources of Concern.

The Oklahoma Department of Wildlife Conservation amended its regulations to designate the Kiamichi River a mussel sanctuary (9 OK Reg. 1909, effective January 1, 1993). As such, the river is closed to all commercial mussel harvest. Although the Ouachita rock pocketbook already receives some protection under Oklahoma law as a state and federal endangered species, designation of the Kiamichi River as a sanctuary provides additional protection by prohibiting activities that might disrupt the species' habitats. Without prohibiting harvest activities, musselers might be required only to separate and return Ouachita rock pocketbooks back to the stream unharmed.

In 1992-1993, The Texas Parks and Wildlife Department designated both Pine and Sanders creeks as mussel sanctuaries, in which no harvest is permitted (Howells *et al.* 1997). As described for the Kiamichi River, the designation of sanctuaries in Texas provides additional protection to *A. wheeleri* populations that may continue to inhabit these waters.

In 1997 and 2000, the Arkansas Game and Fish Commission designated the Ouachita River upstream from U.S. Highway 79B at Camden as a mussel sanctuary, in which no harvest is permitted. As described for Oklahoma and Texas, the designation of this sanctuary in Arkansas provides additional protection to the *A. wheeleri* population that may continue to inhabit these waters.

The U.S. Fish and Wildlife Service (1994a,b) prepared and distributed a draft of this recovery plan in July 1994, providing preliminary information about the species and its recovery needs to other agencies and the general public. Several subsequent surveys and studies discussed in this approved plan were performed to address key information needs identified in the draft plan. From a more general standpoint, a broad group of representatives from federal agencies, state agencies, academia, commercial interests, and private entities produced a national strategy for native mussel conservation (National Native Mussel Conservation Committee 1998), outlining a range of needs and tasks and highlighting their subject as a problem worthy of national attention. Other mussel conservation strategies, more focused in scope, also have been published (e.g., U.S. Fish and Wildlife Service 1994c, 1996, 1997a,b, Jennings 2000, Obermeyer 2000). These, plus formation of a freshwater mollusk conservation association, and evidence of a renewed recent interest in freshwater mussel research (Jenkinson and Todd 1997), indicate an increasing body of knowledge, experience, and appreciation of these organisms that can be applied to their conservation, including recovery of *A. wheeleri*.

The FWS has reviewed a number of federal actions within the range of the Ouachita rock pocketbook and consulted further with other agencies in cases where it appeared those actions might adversely affect the species. The most significant of these consultations to date occurred in regard to replacements of bridges across the Kiamichi River near Tuskahoma and Clayton, both in Pushmataha County, Oklahoma. Through the FWS's work with the Federal Highway Administration and other entities, those projects were modified to avoid significant effects on *A. wheeleri*. Similar planning has occurred in relation to construction of new water treatment facilities and other recent/proposed developments affecting waters inhabited by the Ouachita rock pocketbook. The FWS has begun informal consultation with the CE regarding operation of Sardis Reservoir. The FWS also has provided general comments to State of Oklahoma officials regarding conceptual proposals for water resource development in southeast Oklahoma.

The Nature Conservancy, a private organization, has shown pertinent interest by initiating its own conservation planning for the Ouachita Mountains region (Doug Zollner, TNC, *in litt.* 1994), and by exploring local interest in river conservation specifically within the Kiamichi River watershed (Wilson 1999).

Strategy of Recovery

Many scientific investigations and conservation assessments, historical to recent, have identified the Kiamichi River as an exceptional stream resource, exhibiting a high diversity of native species and an unusual maintenance of that diversity to current times, including rare species (Isely 1925, Clarke 1987, Vaughn *et al.* 1993, 1996, Pyron and Vaughn 1994, Master *et al.* 1998, Bell *et al.* 1999). The Kiamichi River basin is a desirable location to emphasize in initial recovery efforts, because of its natural values and because of the relative ease of maintaining existing high quality conditions versus trying to restore them in more degraded environments. Timely efforts to protect and recover the Ouachita rock pocketbook and its associated ecosystem in the Kiamichi River can in many cases help maintain other valued ecological characteristics of that river, and assist development interests in identifying compatible approaches for human activity.

The Kiamichi River presently supports the only known substantial population of the Ouachita rock pocketbook. Protection of that population, including the conditions that provide for its natural growth and reproduction, is essential to the continued existence of the Ouachita rock pocketbook. Reservoir construction and water quality degradation have caused declines of *A. wheeleri* populations, and remain principal threats to the Kiamichi River population. Measures to achieve protection of the Kiamichi River population are identified as the most important tasks (Priority 1) in this recovery plan.

Existing statutes provide considerable protection, especially the Endangered Species Act, the Clean Water Act, and corresponding state laws and regulations. Additional protection will be required to ensure survival of the Kiamichi River population. Deauthorization of the proposed Tuskahoma Reservoir project is believed necessary to recover the species. Survival and recovery of the Ouachita rock pocketbook cannot be accomplished as long as that threat exists.

Additional life history and ecological investigations are needed to determine the full range of conditions that must be protected. Those studies would determine the host species required by larval Ouachita rock pocketbooks, other critical aspects of reproduction, juvenile habitat requirements, and environmental tolerances. In addition, permanent monitoring of the population and habitat should be conducted to confirm the effectiveness of present and future protection measures. Without determining key aspects/requirements and monitoring for effectiveness, the vital Kiamichi River population could decline further or disappear.

Protection of the Kiamichi River population is believed essential to survival and to provide for the eventual recovery of the Ouachita rock pocketbook. By itself, however, such action would not return the species to a secure status as provided historically by the existence of multiple distinct populations. The existence of multiple, separate populations greatly reduces vulnerability of a species to adverse events impacting a single population, such as spill of a toxic material into an inhabited drainage. Consequently, restoration of Ouachita rock pocketbook populations and habitats outside of the Kiamichi River would benefit survival of the species under conceivable but unintended circumstances (e.g., toxic spills).

Restoration of those populations and habitats also offers the greatest potential for species recovery, because of their presently degraded condition.

Enhancement of the Kiamichi River population, updated assessments of other populations that may still exist, plus restoration and protection of degraded populations and habitat are tasks designed to recover the Ouachita rock pocketbook. Restoration of decimated populations may require translocation of mussels from healthy populations, if techniques can be developed to perform this operation successfully. Additional research will be needed on habitats in other inhabited waters, genetic composition of extant populations, and population viability.

Available information indicates the natural range of the Ouachita rock pocketbook to be portions of the Ouachita River, Kiamichi River, Little River, and two or more small tributaries of the Red River. The small, closely situated Red River tributary portions likely are incompletely isolated from each other (in terms of larval dispersal between mussel populations), and are regarded here as parts of a single area of occurrence, i.e., inhabited by a single metapopulation. Restoration and protection of habitat and viable populations in the four indicated areas or systems would return the species to its total known range. Such reestablishment is identified as necessary before delisting can be considered. Restoration and protection of habitat and viable populations in three areas, including the Kiamichi River, form the basis for considering a reclassification to threatened. The recovery criteria may be revised as the results of additional research, outlined in this recovery plan, become available.

Shared understanding of important facts and concerns, and meaningful involvement of the public, will significantly influence the success of any recovery effort. Tasks have been incorporated into this plan that are designed to enhance communication and public participation. These tasks will contribute to the success of other recovery tasks.

The Ouachita rock pocketbook has always been reported as rare, even in its most favorable habitats, making its natural propagation especially vulnerable to loss of individuals. Survey, monitoring, and research efforts, although crucial elements of recovery, must be carefully designed and conducted to minimize impacts on wild populations. Management efforts must likewise avoid impacting wild populations while treating threats adequately.

Use of existing statutes to protect the Kiamichi River system; deauthorization of Tuskahoma Reservoir; monitoring of the Kiamichi River population, its habitat, and threats; determination of the host species and other reproductive details; and determination of environmental sensitivities are all priority one tasks identified by this plan. Priority one tasks are actions that must be taken to prevent extinction or to prevent the species from declining irreversibly in the foreseeable future. Restoration, protection, and monitoring of degraded populations and habitats; certain ecological investigations; and conducting a public outreach program are the most important priority two tasks.

Any recovery task proposed to be carried out by a federal agency is subject to the provisions of the National Environmental Policy Act (NEPA) if that task constitutes a major federal action. Such actions will only be implemented in compliance with NEPA and would undergo complete public review and comment prior to implementation. Recovery plans do not obligate an agency, entity, or persons to implement the various tasks listed in the plan.